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REPRODUCTIVE BIOLOGY AND PREDATORY BEHAVIOUR OF THE ANTHOCORID BUGS (ANTHOCORIDAE : HEMIPTERA) ASSOCIATED WITH THE COCONUT CATERPILLAR, *OPISINA ARENOSELLA* (WALKER)

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Some aspects of the biology of three predatory bugs, viz., *Cardiastethus exiguus, C. affinis* and *Buchananiella sodalis*, found in the galleries of *Opisina arenosella*, the black-headed caterpillar pest of coconut were studied. The life-cycles of the three bugs are presented. The predatory and cannibalistic behaviour, reproductive biology and longevity of the adults were investigated. Field studies regarding their effectiveness as predators of *O. arenosella* were carried out and the findings are discussed.

(*Key words*: *Cardiastethus exiguus, C. affinis, Buchananiella sodalis, Opisina arenosella*, reproduction, predatory behaviour, cannibalism)

INTRODUCTION

Opisina arenosella (WALKER), the black-headed caterpillar pest of coconut plam, is attacked by several parasites and predators. The predators include the flower bugs (Hemiptera : Anthocoridae) which were also reported to feed on aphids, thrips, eggs and larvae of stored product insects and other small insect pests. BARBER (1936) gave an extensive account of *Orius insidiosus* and its role in the control of cornworm, *Heliothis obsoleta*. RAJASEKHARA & CHATTERJI (1970) reported *Orius* as a common predator of *Taeniothrips nigricornis*, a thysanopteran that attacks the flowers of an important leguminous plant, *Cajanus cajan*. *Anthocoris nemorum* was found to be an important natural control agent of the pests of top fruit, notably apples and pears (HILL, 1957; ANDERSON, 1961 ; COLLYER, 1967). *Xylocoris flavipes* was effective in suppressing the populations of several stored product insects (JAY *et al.*, 1968). Anthocorids serve as efficient biocontrol agents of thrips (ANANTHAKRISHANAN & SURESHKUMAR, 1985). AVELING (1981) noted an effective role of *Anthocoris* sp. in the integrated control of damson-hop aphid, *Phorodon humuli*. RAO *et al.* (1948) reported *Orius* sp. as a predator of the eggs of *Opisina arenosella*, while ABDURAHIMAN *et al.* (1982) reported *Cardiastethus* sp. as a predator of the eggs and early stage larvae of the same insect pest. The present authors for the first time report three species of anthocorid bugs, namely *Cardiastethus exiguus, C. affinis* and *Buchananiella sodalis* as predators of the eggs and first instar larvae of *Opisina arenosella*. The bugs were recovered from the galleries of the coconut caterpillar collected from different parts of Kerala.

The present paper is designed to give an idea of the biology of these anthocorid bugs, with an attempt to evaluate their role in the biological control of *O. arenosella*.

MATERIALS AND METHODS

The bugs were reared in the laboratory in glass tubes measuring 5 cm × 2 cm, closed with cotton plugs. Fresh eggs and larvae

of *Opisina arenosella* were supplied daily as food. Coconut leaf strips provided in the tube served as oviposition substratum. The stock culture was maintained on *Corcyra cephalonica* eggs in 100 ml beakers. Studies on cannibalistic behaviour were conducted by observing the predation of nymphs and adults on eggs, the predation by nymphs on other nymphs and the predation of adults on nymphs. Studies were carried out under the laboratory temperature, 28.03 ± 1.28°C and Relative Humidity, 56 ± 7.47. Regular field observations and collections were also made.

OBSERVATIONS AND RESULTS

1. *Cardiastethus exiguus:*

Cardiastethus exiguus (=*C. pygmaeus pauliani*) was reported from South India by MURALEEDHARAN (1975) from the nests of *Ploceus philippinus*.

The creamy white eggs are cylindrical and slightly curved, with an operculum at one end. The newly laid egg measures 0.52 mm in length and 0.16 mm in width. It develops a reddish tinge within a day, the colour darkening as eclosion nears. The incubation period lasts for 3 – 5 days. The nymphs are reddish with three, dark spots on the 3rd, 4th and 5th abdominal segments. Wing pads appear during the 3rd instar. The measurements and the duration of each instar are given in Tables 1 and 2 respectively.

The newly emerged adult is pale red in colour with creamy white wings, but gradually takes on a dark brown colour. The adult female (Fig. 1) is larger than the male with a slender body and measures 1.7 to 1.9 mm in length and 0.58 to 0.67 mm in width. The adult male measures 1.6 to 1.8 mm in length and 0.50 to 0.60 mm in width, while the gravid female measures 2 to 2.18 mm in length and 0.65 and 0.75 mm in width. Rostrum is four segmented. The adults are dark brown in colour. Egg laying female has its abdominal end jutting beyond the posterior margin of the wings.

Predatory behaviour: The nymphs and adults feed on the eggs and 1st instar larvae of *O. arenosella*. The eggs of the prey are sometimes simply pierced and not fed upon. Such eggs are also damaged reducing the population of the pest, thus enhancing the efficiency of the bug as a biocontrol agent. The bug feeds on 200 to 225 eggs in a life time (from first instar onwards), excluding those eggs which are just pierced. The egg-laying female consumed more number of eggs than the other females and males.

Apart from *O. arenosella*, the bug also feeds on the eggs and larvae of *Corcyra cephaalonica* (Staint) (Pyralidae), *Anadevidea peponis* (Noctuidae), *Orthaga exvinacea* (Noctuidae), *Bracon brevicornis* Wesm. (Braconidae) and *Goniozus nephantidis* (Meus.) (Bethylidae). This indicates that the bug shows no strict specificity with regard to its host prey selection.

C. exiguus exhibits cannibalism when food is scarce. The older nymphs often feed on younger nymphs. The gravid females are found to be more cannibalistic than the unmated females or males. However, gravid females occasionally feed on the eggs nearing eclosion unlike what has been reported for *Xylocoris flavipes* (ARBOGAST, 1979). This cannibalistic behaviour has an advantage as it helps in the survival of the bugs when the prey population is scarce.

Reproductive biology: Females are more receptive immediately after emergence. When the male meets the female, he arches his back, bends the forelegs and inclines his head, the antennae being held forward in a 'V' position. The male now starts its sho-

TABLE 1. Summary of measurements (in mm).

Instar/ Sex	Body length	Head		Thorax		Abdomen		Rostrum	Wing bud	Antennae
		Length	Breadth	Length	Breadth	Length	Breadth	Length	Length	Length
	Cardiastethus exiguus									
I	0.693–0.777	0.126–0.168	0.147–0.168	0.105–0.210	0.168–0.210	0.336–0.504	0.231–0.252	0.315–0.357	—	0.294–0.336
II	0.966–1.05	0.714–0.21	0.714–0.21	0.294–0.336	0.252–0.336	0.462–0.546	0.294–0.336	0.336–0.378	—	0.336–0.378
III	1.197–1.302	0.231–0.252	0.231–0.252	0.336–0.42	0.357–0.399	0.609–0.672	0.42 –0.546	0.378–0.42	0.126–0.147/0.126–0.147	0.42
IV	1.428–1.512	0.228–0.252	0.227–0.252	0.42	0.42	0.714–0.756	0.504–0.546	0.462–0.546	0.378	0.504
V	1.638–1.827	0.168–0.252	0.336	0.504–0.63	0.378–0.504	0.84 –0.924	0.588–0.672	0.588–0.63	0.546–0.588	0.588–0.63
Adult ♀	1.764–2.184	0.21 –0.294	0.315–0.336	0.588–0.63	0.63 –0.714	0.966–1.323	0.63 –0.756	0.588–0.672	1.218–1.344	0.609–0.672
Adult ♂	1.596–1.764	0.21 –0.294	0.294–0.336	0.546–0.609	0.546–0.651	0.84 –1.05	0.588–0.714	0.546–0.63	1.134–1.302	0.546–0.63
	Cardiastethus affinis									
I	0.588–0.672	0.168–0.189	0.168	0.21 –0.231	0.504–0.546	0.378–0.42	0.252–0.294	0.252–0.294	—	0.294
II	0.798–0.84	0.189–0.21	0.21 –0.294	0.21 –0.252	0.252–0.336	0.504–0.546	0.336–0.42	0.336–0.378	—	0.336–0.378
III	0.882–0.924	0.21 –0.231	0.21 –0.336	0.294–0.315	0.294–0.42	0.63 –0.672	0.42 –0.546	0.42 –0.462	0.126–0.168/0.21 –0.252	0.462–0.483
IV	1.134–1.386	0.252–0.273	0.252–0.336	0.462–0.525	0.336–0.42	0.714–0.756	0.504–0.714	0.504–0.546	0.336–.378	0.588
V	1.512–1.68	0.252–0.294	0.294–0.336	0.504–0.546	0.504–0.546	0.798–0.84	0.714–0.798	0.588	0.588–0.63	0.63 –0.651
Adult ♀	1.554–1.68	0.252–0.294	0.294–0.336	0.588–0.63	0.63 –0.672	0.84 –0.882	0.798–0.924	0.672	1.218–1.26	0.714–0.756
Adult ♂	1.596–1.68	0.252–0.294	0.294–0.336	0.63 –0.672	0.588–0.63	0.882–0.966	0.672–0.756	0.63	1.302–1.344	0.714–0.798

TABLE 2. Developmental period of immature stages of *Cardiastethus exiguus*, *C. affinis* and *Buchananiella sodalis*.

	Incubation period (in days)	I instar (in days)	II instar (in days)	III instar (in days)	IV instar (in days)	V instar (in days)
Card. exiguus	3 – 5	3 – 5	2 – 3	2 – 3	3 – 4	4 – 5
Card. affinis	3 – 4	4	2 – 3	2 – 3	2 – 3	5 – 6
Buch. sodalis	3	2 – 3	3	3 – 4	2 – 3	4 – 5

velling action by pushing the ventral aspect of the abdomen of the female. The female shows a negative response by taking a position on the back of the male and moves to and fro thereby disallowing the male to mount. The shovelling movement of the male lasts for 10 to 15 seconds. The male then suddenly withdraws from the female and mounts on her back. During mounting the male holds the prothorax of the female with his forelegs and bends the tip of his abdomen to introduce the aedeagus into the female genital tract through the right side of her abdomen. After coupling the male remains attached to the female with the help of the genital organ only, the body of the male being kept in a vertical position with respect to the female. Mating lasts for 3 to 6 minutes.

The pre-oviposition period lasts from 5 to 7 days. A female lays 75 to 250 eggs in her lifetime and often dies soon after oviposition is completed. The egg laying rate is graphically represented (Fig. 4). The number of eggs laid throughout the oviposition period is rather uniform, except for the first week and last week. An egg laying female ceases to lay eggs when food supply is terminated, but resumes laying eggs when food is again supplied. This is significant as the egg-laying female can tide over a period of shortage of prey in the field, and regaining her power when the prey becomes available. Virgin females may lay unfertilized eggs; parthenogenesis is not recorded so far. Males mate many times during their life span, but females mate only once. An ovipositing female lived for 45 to 50 days, while virgin females lived for an average number of 126 days. In the laboratory, the maximum number of eggs were laid during the period from May to October, while it was the lowest during November to January.

In the field the eggs are laid horizontally and remain stuck either to the frass or to those parts of the leaf partially fed upon by *Opisina arenosella* larvae. Eggs are neither laid on the green parts of the leaf nor are inserted into the leaf tissue. The oviposition takes place at the rate of 2 – 3 eggs per day, but as the female gets older, this frequency is reduced. In the laboratory, when they were reared in glass tubes, the eggs are laid on the cotton plug and also on the bottom and sides of the tube. Eggs laid during a 24 hour period are found close to one another.

Fig 1 Cardiastethus exiguus

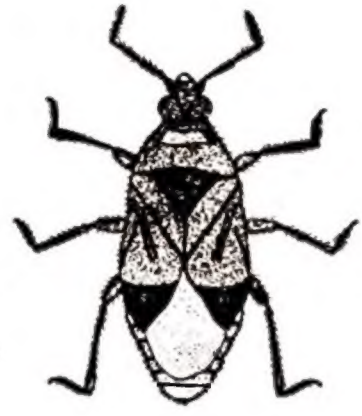

Fig 2 C. affinis

Fig 3 Buchananiella sedalis

2. *Cardiastethus affinis*:

This species was first reported from India by MURALEEDHARAN *et al.* (1978). The present authors have recovered them from the galleries of *Opisina arenosella* collected from Kappad, Kerala.

Eggs of *C. affinis* are pear shaped with one end swollen, while the other end narrows down into a circular operculum. Newly laid egg is almost transparent and measures 0.50 mm in length and 0.21 mm in width. The colour of the egg becomes yellowish orange within a day and gradually changes to pink when it is about to hatch. The incubation period lasts for 3 to 4 days. During hatching, the operculum is opened to one side and the nymph emerges out. The first instar nymph is mostly yellowish in colour with three reddish orange coloured spots on the abdomen, but as the nymphs get older the abdominal spots get fainter. The first instar nymph shows marked colour difference indicating the sex of the adult: the yellow coloured ones develop to males and the orange coloured ones to females. This colour difference becomes less pronounced as the nymph gets older. The total duration of the 5 nymphal instars extend from 17 to 19 days. The measurements and duration of each instar are given in Tables 1 and 2 respectively.

The newly emerged adult is pale yellowish orange in colour, with creamy white wings; but the colour changes to light brown within one day along with the appearance of two dark spots on the hemelytra. The adult male having a narrow abdomen is smaller than the female. The male measures 1.55 to 1.6 mm in length and 0.65 to 0.75 mm in width and the female 1.55 to 1.89 mm in length and 0.80 to 0.90 mm in width. Rostrum is four segmented. The abdomen of the egg-laying female (Fig. 2) projects beyond the posterior margin of the wing and is clearly swollen.

Predatory behaviour: It has lower rate of feeding, when compared to *C. exiguus*. The maximum number of eggs (of *O. arenosella*) consumed per day by the first instar nymph, the adult and the egg laying female are 2, 5 and 7 respectively. The adult bug rarely feeds on first instar larvae, as the escape

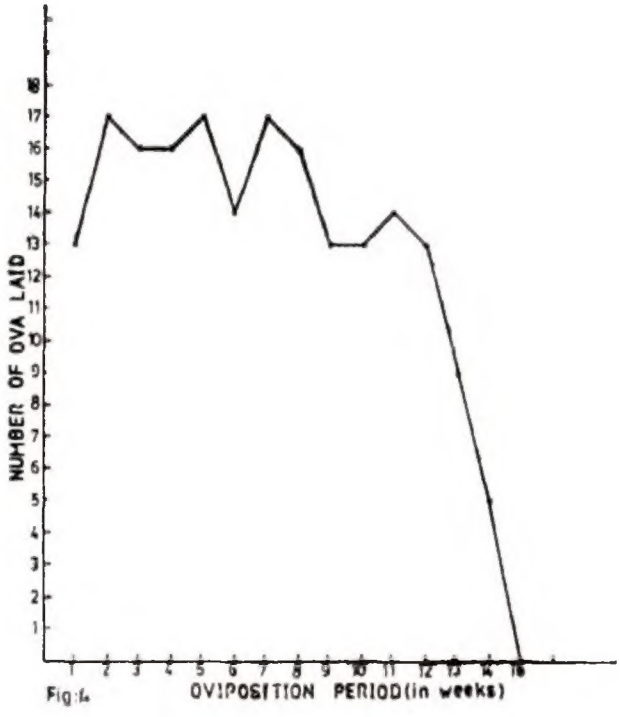

Fig. 4. Pattern of oviposition of *Cardiastethus exiguus*.

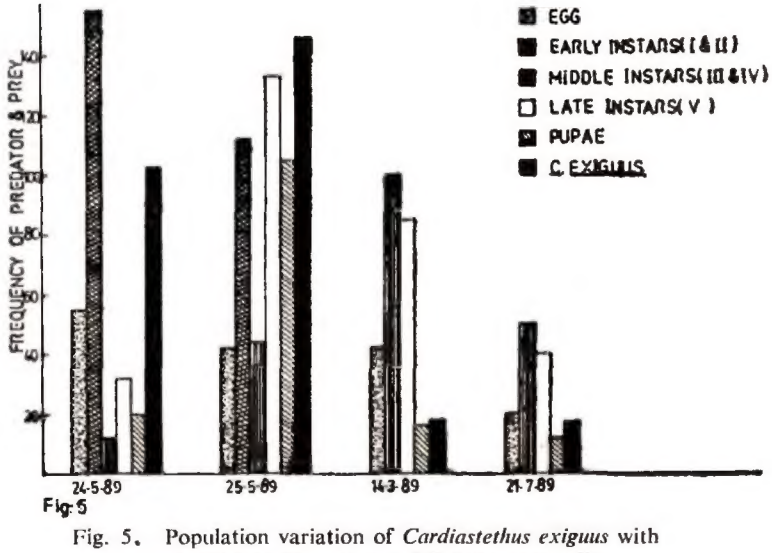

Fig. 5. Population variation of *Cardiastethus exiguus* with regard to various stages of *Opisina arenosella*.

reactions of the larvae always discourage the bugs from chasing them. Piercing of the eggs without feeding, as observed in the case of *C. exiguus*, is not seen here.

This bug is also polyphagous and feeds on the eggs of *Corcyra cephalonica* (Pyralidae), *Plusia peponis* (Noctuidae) etc. Cannibalism occurs very rarely. The adults live for 125 to 156 days, the females having maximum longevity.

Reproductive behaviour: The females are receptive soon after they moult into adults; the males, however, mate only a day after they moult. The sexes meet and feel each other with the antennae, followed by the male mounting the female. During mating the males hold on to the female with their legs unlike what is seen in *C. exiguus*. Females remain still during mating and only after consecutive matings do they try to shake off the male. Females may mate 2 to 3 times in a 24 hour period and they may mate even after completion of laying one batch of eggs. Males also mate a number of times. Mating lasts for 30 to 60 seconds. The pre-oviposition period lasts for 3 days. The bug lays 58 to 138 eggs. Parthenogenesis is not observed.

As in *C. exiguus* the eggs are laid stuck to the surface of the culture tube or on the substratum provided. The females lay eggs at a rate of 3 – 4 eggs per day. Eggs laid in a 24 hour period are not grouped together as observed in *C. exiguus*. All mated females do not lay eggs.

3. *Buchananiella sodalis*:

Buchananiella sodalis collected for the first time from the galleries or *O. arenosella*, occur in almost all parts of Kerala. Eggs are cylindrical in shape but more elongated than those of the two species mentioned above; with a circular operculum at one end.

The egg measures 0.55 mm in length and 0.20 mm in width. The newly laid eggs are creamy white in colour. It acquires a reddish tinge after a day and the colour darkens as eclosion nears. The first instar nymph is red in colour, and as in other anthocorids, three abdominal spots are seen. Though red coloured when emerged, the adult when fully developed becomes brownish black, with black colour predominating at the edges of the pronotum and the terminal thinner part of the hemelytra. The hemelytra has two black spots, one on each wing. The female (Fig. 3) is larger than the male and measures 2.1 mm in length and 0.75 mm in width. The male measures 1.9 mm in length and 0.60 mm in width. The duration of each instar is provided in Table 2.

Reproductive and feeding behaviour: *Buchananiella sodalis* shows remarkable similarities with *Cardiastethus* spp. Mating is seen immediately after emergence in the female, and of the few cases observed, older females also mate. No specific courtship pattern is exhibited. When the two sexes meet, the male instantly mounts the female. Males are more aggressive than the two previous cases. Mode of oviposition is the same as already described in the case of the previous species.

With regard to the feeding behaviour, *B. sodalis* appeared to be more aggressive than the other two species and readily feeds on the eggs and larvae of the host. Other aspects of the feeding behaviour, like mode of predation, prey selection, etc. show similarities to *C. exiguus* and *C. affinis*. Cannibalism is more frequently met with, as the adults are found to attack each other even when there is no shortage of food.

DISCUSSION

Cardiastethus exiguus has a distribution all over Kerala, occurring in large numbers in the coconut palms infested with the eggs,

early stage larvae and pupae of *Opisina arenosella*. *Buchananiella sodalis* occupies the second position in abundance, but compared to *C. exiguus* its population is very low and is localised in distribution. This may be due to their high susceptibility and sensitivity to the environmental limiting factors, lower fecundity rate, etc. The aggressive nature of the bug is advantageous for their survival rate. However, this habit makes them less effective from the biocontrol point of view, as they cause considerable damage to the other predator populations inhabiting *Opisina* galleries. Of the three species of bugs, *Cardiastethus affinis* is the least in abundance. It was collected in few numbers, only from *Opisina* infested coconut palms in Kappad (near Calicut). The bug is inactive, sluggish and its feeding rate is low. Fecundity when compared to *C. exiguus* is low. Therefore its effectiveness as an important predator in checking the population of the pest appears to be doubtful.

Of the three predators discussed above, *Cardiastethus exiguus* evidently serves as an important predator of *Opisina arenosella*. Field studies clearly indicate the occurrence of concomitant fluctuation in the population of *C. exiguus* along with that of the eggs and early stage larvae of *Opisina arenosella* (Fig. 5). *Also*, its ability to suspend oviposition when the prey is scarce and to resume it (even after starvation for a week) when prey supply is adequate, are adaptations to tide over unfavourable conditions.

Though this bug feeds on the immature stages of the important larval ectoparasites of the pest (like, *Bracon brevicornis* and *Goniozus nephantidis*), the damage caused to these biocontrol agents is not so serious, as the bug population is very low when these ectoparasites are abundant in the field. *C. exiguus* exhibits high reproductive potential and can also be very easily mass cultured in the laboratory on the eggs of *Corcyra cephalonica*, unlike *C. affinis* and *B. sodalis* where the rate of increase in the population build up is very low.

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AN ARTIFICIAL DIET FOR THE TEAK DEFOLIATOR, *HYBLAEA PUERA* CRAMER (LEPIDOPTERA: HYBLAEIDEA)

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An artificial diet containing teak leaf powder, Kabuligram flour and other commonly available ingredients was developed for rearing the teak defoliator, *Hyblaea puera*. Growth and development of 3—4 days old larvae (initially established on teak leaf) on two diet combinations is compared with that on teak leaf. One of the diets was found to be better than teak leaf with respect to percentage survival and pupal weight.

(*Key words*: artificial diet, *Hyblaea puera*, teak defoliator, teak)

INTRODUCTION

Hyblaea puera Cramer (Lepidoptera: Hyblaeidae) is an important pest of teak in India (BEESON, 1941; NAIR *et al.*, 1985). One of the handicaps in studies dealing with this insect is the difficulty in maintaining a larval culture in the laboratory round the year, due to nonavailability of tender teak leaves during certain seasons and mortality of larvae caused by various pathogenic organisms, particularly virus. In addition, maintaining the larvae on teak leaves demand considerable man power and time. Attempts were therefore made to standardise an artificial diet using cheap and easily available ingredients.

MATERIALS AND METHODS

Test diets:

The test diets were based on that developed by NAGARKATTI & PRAKASH (1974) for rearing *Heliothis armigera* (Hub.) (Lepidoptera : Noctuidae). Necessary modifications were made based on repeated trials to suit the requirements of *H. puera*. The composition of two diets D1 and D2 developed after preliminary trials and evaluated in this study are given in Table 1.

To prepare the teak leaf powder, fully expanded first and second pair of terminal leaves were collected from flushing branches and dried in a hot air oven at 60°C for 12 h. After removing the major veins the leaves were powdered in a blender. The fine dust obtained after seiving out the coarser particles was used. All the other ingredients were commercially available.

Diet preparation:

The ingredients of the diets are given in Table 1. Agar was added to half the required quantity of distilled water in a beaker, stirred with a glass rod and brought to boil. The beaker was then removed and kept immersed in hot water to prevent solidification of agar.

Kabuligram, leaf powder, yeast extract, sorbic acid, casein/casein hydrolysate, and methyl parahydroxybenzoate were added to the other half of the distilled water in a blender jar and blended. To this was added the

TABLE 1. Composition of artificial diets evaluated for rearing *H. puera*.

	Ingredients	Quantity of ingredients	
		Diet 1	Diet 2
1.	Agar[1]	20 g	20 g
2.	Kabuligram flour (*Cicer arietnum*)	100 g	100 g
3.	Casein (purified)[1]	30 g	—
4.	Casein hydrolysate[1]	—	3 g
5.	Yeast extract powder[1]	10 g	10 g
6.	Teak leaf powder	20 g	20 g
7.	Multivitamin and mineral mixture[2]	2 caps	2 caps
8.	Vitamin E[3]	400 mg	400 mg
9.	Ascorbic acid[4]	3.5 g	3.5 g
10.	Sorbic acid	1 g	1 g
11.	Mythyl parahydroxybenzoate[6]	1.5 g	1.5 g
12.	Streptomycin sulphate[6]	0.25 g	0.25 g
13.	Formaldehyde 10%	2 ml	2 ml
14.	Distilled water	1000 ml	1000 ml

1 – Supplied by Hymedia Ltd.;

2 – 'Becadexamine' capsule by Glaxo Ltd. containing Vitamin A 5000 IU, Vit D3 400 IU, Vit. E 15 mg, Vit. B_1 5 mg, Vit. B_2 5 mg, Vit. B_6 2 mg, Vit. B_{12} 5 mg, Vit. C 75 mg, Nicotinamide 45 mg, D–Panthenol 5 mg, Folic acid 100 mg, Ferrous fumerate 50 mg, Dibasic calcium phosphate 70 mg, Copper suplhate 0.1 mg, Manganese sulphate 0.01 mg, Potassium iodide 0.025 mg, Manganese oxide 0.15 mg, and Zinc sulphate 50 mg.

3 – Evion by Merck (2 caps);

4 – Supplied by Polypharm;

5 – Supplied by Romali;

6 – Ambystryn by Sarabhai Chemicals.

multivitamin mineral mixture, ascorbic acid, streptomycin and formalin and the mixture was further blended.

Agar solution cooled to 60°C was then slowly poured to the above mixture and blended.

The diet was poured hot into sterilised glass tubes (7.5 cm × 2 cm) upto about one third of the tube. This quantity of diet was sufficient for complete development of a larva. One litre of the diet was sufficient to prepare about 100 such tubes. The tubes were then covered with paper and allowed to cool at room temperature.

Test insects:

To collect eggs, mated female moths were released into 17 cm × 7 cm glass bottles and covered with muslin cloth. Diluted honey (10%) was provided as food on cotton swabs. Eggs were mostly laid on the muslin cloth

which made collection of eggs easy. As a measure to prevent mortality due to diseases, eggs were surface sterilized by dipping the muslin cloth containing the eggs in a 1% solution of sodium hypochlorite for 15 min. The cloth was then dipped in distilled water for 10 min with 2–3 changes and then kept over a blotting paper for draining off water. It was then placed in a glass bottle for hatching of eggs. The newly emerged larvae were allowed to feed on fresh teak leaves sprayed with a 200 ppm solution of streptomycin sulphate for 1–2 days before transferring to the diet.

Transfer of larvae.

Larvae initially established on tender teak leaves were transferred to the diet when they were 3–4 days old (second instar). Using a fine camel hair brush a single larva was transferred to each tube containing the diet. The tubes were then closed with cotton plugs. A set of 75 tubes were maintained for each diet. An equal number of larvae maintained on teak leaves formed the control. For this, five larvae each were maintained in 17 × 7 cm glass bottles. The bottles were changed once in two days and fresh treak leaves sprayed with antibiotic solution were provided every day. The rearing was carried out at room temperature (24–26°C and RH 81–92%) during August–September.

The pupae were removed from the rearing containers within 24 h of pupation and transferred to clean bottles for emergence.

The parameters measured in this study to evaluate the suitability of the diets were: (1) larval period, (2) pupal period, (3) percent pupation, (4) pupal weight and (5) percent emergence of normal adults.

The data were analysed statistically using analysis of variance and mean comparison test (SNEDECOR & COCHRAN, 1967).

RESULT

The performance of the two diets D1 and D2 (Table 1) in comparison to teak leaf with respect to the parameters studied is shown in Table 2. Survival in terms of percent emergence of the moth was highest on diet D1. Even on teak leaf, the natural food, only 18% of the larvae survived to the adult stage, although 27% had pupated. This was largely due to wandering off of larvae from the leaf. Cut teak leaf has a tendency to loose turgidity quickly even when the petiole is wrapped in moist cotton. In addition some larvae died due to bacterial or viral infection. On diet D2 although 44% pupated a larger percentage died as pupae. On both the diets the total developmental period was slightly higher than on leaf, but for diet D1 this difference was not significant. The insect reared on both the diets showed higher pupal weight than those reared on leaf. A comparison of all parameters studied among the two diets and teak leaf (Table 2) will show that diet D1 was equal or better than teak leaf with respect to total developmental period, percent survival and weight of the insect. A slightly longer developmental period although not statistically significant was compensated by a significantly higher pupal weight. Between the two diets, those reared on D2 had a significantly longer developmental period and significantly lower survival rate.

The general trend obtained in this experiment was noticed in several subsequent rearings on diet D1 showing that it is a satisfactory artificial diet. Several continuous generations were maintained on diet D1 in the laboratory and no malformation was noticed.

DISCUSSION

The basic composition of the diet used in our experiment was similar to that developed by NAGARKATTI & PRAKASH (1974) for

TABLE 2. Comparative performance of two artificial diets and teak leaf (control) evaluated for rearing *H. puera*.

Treatment	Larval period* (days)		Pupal period (days)		Total development period		Percent pupation	Pupal weight (mg)		% emergence out of pupae	% emergence out of initial no. of larvae
	Mean	SD	Mean	SD	Mean	SD		Mean	SD		
Control (Leaf)	11.9^{a}	± 0.86	7.3^{a}	± 0.59	19.3^{a}	± 1.08	27^{g}	180.5^{b}	± 34.99	59.3^{a}	18^{a}
Diet–D_1	13.5^{b}	± 0.98	6.7^{b}	± 0.72	20.1^{a}	± 1.25	56^{h}	223.4^{a}	± 43.42	78^{b}	44^{b}
Diet–D_2	14.3^{c}	± 0.76	7.3^{a}	± 0.65	21.6^{b}	± 1.08	$44^{a,b}$	207^{a}	± 27.6	33^{a}	16^{a}

Figures superscribed by the same letters in each column are not significantly different at 5% level.

* includes the period reared on leaf.

Heliothis armigera. The alterations we made consisted of addition of casein and teak leaf powder; replacement of yeast with yeast extract, as well as changes in the quantity of various ingredients. These changes were made on an empirical basis and no attempt was made to arrive at the optimal composition or optimal relative concentration of the ingredients. We made a series of trials using various combinations of the ingredients before arriving at the two combinations used in diet D1 and D2. Apparently addition of teak leaf powder increased the acceptability of the diet to the larvae by arresting their tendency to wander away from the diet. Neither dried teak bark powder nor teak saw dust gave this effect.

The only difference between diet D1 and D2 was use of casein in diet D1 (30g) and casein hydrolysate (3g) in diet D2. Only a small quantity of casein hydrolysate was used since Kabuligram powder was present as the chief protein source. The result showed that presence of hydrolysed protein in the form of casein hydrolysate was disadvantageous.

The diet D1 developed in this study was suitable for rearing *H. puera* for several repeated generations, but the composition was empirical. Apparently there is scope for simplifying the diet further by eliminating nonessential components. The present diet may be taken as the base diet and improvement attempted. General observations showed that storing the diet for a period of 2 to 3 months in a refrigerator had no deleterious effect on survival of the insect.

It must be noted that we used 3 – 4 days old larvae that were initially fed on teak leaves. Freshly hatched larvae often failed to establish on the diet, but the reason remains unknown. It appears that the texture of the diet is important in initial larval establishment. The newly hatched larvae established more readily when the surface of the diet was scratched with a sterile needle. Further trials are needed to arrive at an optimal diet composition and to standardise the physical conditions of the diet to facilitate the establishment and survival of newly hatched larvae. In spite of the precautions taken some larvae died due to bacterial or

viral infection, in our experiments. Much of this infection must have occurred before the larvae were placed on the diet. This can be prevented if conditions are standardised for direct transfer of the larvae on to the diet.

ACKNOWLEDGEMENT

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BIOLOGY OF *ELASMUS BREVICORNIS* GAHAN (HYMENOPTERA: ELASMIDAE) A PARASITE OF THE PUMPKIN CATERPILLAR, *DIAPHANIA INDICA* (SAUNDERS) (LEPIDOPTERA : PYRAUSTIDAE)

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Elasmus brevicornis Gahan is a gregarious larval ectoparasite and its biology has been studied for the first time on *Diaphania indica*. It preferred the third instar host larva for oviposition. Before oviposition, the host larva was completely paralysed. The average number of eggs laid per larva was 13.68 and out of this 8.60 adults emerged. The total life cycle from egg to adult emergence took 9 to 14 days. A description of the various immature stages is also given.

(*Key words*: *Elasmus brevicornis*, biology, biological control)

INTRODUCTION

Elasmus brevicornis Gahan was first described as a primary parasite of *Erionata thrax* Linn. (FERRIERE, 1929). It is distributed in India, Burma, Java and Malaya. In India, it is reported to parasitise *Aproaerema modicella* (Lepidoptera: Gelechiidae); *Cnaphalocrocis medinalis* (Lepidoptera Pyrasutidae); *Eutectona machaeralis* (Lepidoptera: Pyraustidae); *Lamprosema indicata* Lepidoptera : Pyraustidae) ; *Lygropia quaternalis* (Lepidoptera : Pyraustidae); *L. obrinusalis; Marasmia suspicalis* (Lepidoptera : Pyraustidae); *Nausinoe geometralis* (Lepidoptera : Geometridae); *Sylepta derogata* (Lepidoptera : Pyraustidae) and *Apanteles machaeralis* (Hymenoptera : Braconidae) (VERMA & HAYAT, 1986). This species was also observed to be facultative hyperparasite since it was recorded both as a primary as well as secondary parasite. In the present study *E. brevicornis* was reared for the first time as a gregarious ectoparasite of *Diaphania indica*, a serious pest of cucurbits. Considering its importance as a major parasite of this pest on cucurbits, its biology was investigated.

MATERIALS AND METHODS

Rearing and maintenance of stock culture:

The field collected parasite cocoons were placed inside glass specimen tubes until emergence of adults. On emergence the adults were fed with honey solution and allowed to mate for 24 h. The adults were confined in the ratio of 1:2 (male : female). At the end of 24 h the females were separated out for egg laying. Twenty second instar larvae of *D. indica* were taken on a bouquet of *Coccinia* leaves partly inserted inside a glass vial with water. This was placed inside a plastic jar (13.5 × 11 cm), with wire-mesh fitted lid. Five mated females of *E. brevicornis* were released into the jar for oviposition. After an exposure period of 24 h the females were removed from the jar. The paralysed larvae were placed separately in specimen tubes for the development of the

parasite larva. After pupation, the pupae were retained in the same tube until emergence.

Life history and morphology of immature stages:

The experiments were conducted in an insectary at 26.43 ± 2.53°C and 65.08% RH. For studying the biology of the parasite, freshly emerged males and females were drawn from the stock culture and were confined in the ratio of 1:2 (male : female) in specimen tubes for mating. After 24 h five mated females were taken out and introduced into plastic jars containing *Coccinia* leaves. Twenty five, second instar larvae were released. After an exposure period of three hours, the paralysed larvae were removed and placed individually in specimen tubes and observations made. Measurements as well as diagrams of the various life history stages were recorded. The fecundity was studied by keeping 10 mated females with host larvae and recording the number of eggs laid each day until the females died. To determine the host stage preferred for oviposition the different instars (1 to 4) of *D. indica* larvae were exposed to mated females. Ten replications were maintained with five larvae of each stage per replicate. The total number of larvae of each instar parasitised were recorded to determine the most preferred host stage. The immature stages were measured with a calibrated ocular micrometer and drawn using a camera lucida attached to a compound microscope.

RESULTS AND DISCUSSION

Morphology

(*i*) *Egg:* Shining white, long, slightly curved in the middle, smoothly rounded at the ends and one end remaining slightly narrower than the other (Fig. 1). The chorion is unsculptured. Length 0.30 mm and width at the middle 0.11mm (Table 1). In *E. claripennis* Cam. the egg has a short peduncle at the narrow end and in *E. nudus* Nees the chorion is covered with minute tubercles (PARKER, 1924).

(*ii*) *Larva:* The freshly hatched larva is white, transluscent, hymenopteriform, with a rounded head and thickset body (Fig. 2) The freshly hatched larva measured 0.42 mm in length and 0.15 mm in width. There are three larval instars with mean lengths ranging from 0.42 mm to 1.88 mm for the first and third instars, respectively. The full grown larva is featureless, thick-

TABLE 1. Mean size and duration of immature *E. brevicornis* reared at 26.43 and 65.08% RH.

Stage	n	Length (mm) $\bar{x} \pm$ SEM	Width (mm) $\bar{x} \pm$ SEM	Duration (days)
Egg	25	0.30±0.03	0.11±0.01	0.75–1.0
1st Instar	20	0.42±0.02	0.16±0.02	1–2
2nd Instar	20	1.16±0.04	0.45±0.03	1
3rd Instar	16	1.88±0.14	0.76±0.21	1–2
Prepupa	16	1.77±0.03	0.71±0.13	1–2
Pupa	12	1.74±0.41	0.55±0.18	4–6

set and length ranged from 1.03 to 1.92 mm and width 0.74 – 0.78 mm (Fig. 3). The mandible of the third instar larva is pointed, dagger-shaped and well chitinized at the tip and measures 0.22 mm in length (Fig. 4). Except for the size, the shape of the mandible is the same in all the instars.

The first instar larvae of the other species of *Elasmus* studied are hymenopteriform, with distinct segmentation and the body widest in the anterior abdominal region. In *E. nudus*, the body is cylindrical (PARKER, 1924). *E. hispidarum* bears a row of retractile intersegmental pseudopodia on the median line both dorsally and ventrally (TAYLOR, 1937). These are protruded only when the body is fully extended and presumably serve a locomotory function within the host leaf mine. In *E. brevicornis* these structures are absent probably because very little movement of the parasite larva occurs. The pupation is close to the host while in *E. hispidarum* the full grown larva moves some distance away from the dead host and pupates (TAYLOR, 1937).

(*iii*) *Pupa:* The pupa is dark brown in colour and measures about 1.74 mm in length and 0.55 mm in width. It is naked and the appendages are fused to the body giving it a mummified appearance (Figs. 5, 6). Generally they are found on the leaf surface near the host remains in an upright position with its posterior end firmly fixed to the leaf. The meconial pellets are present near the naked pupa.

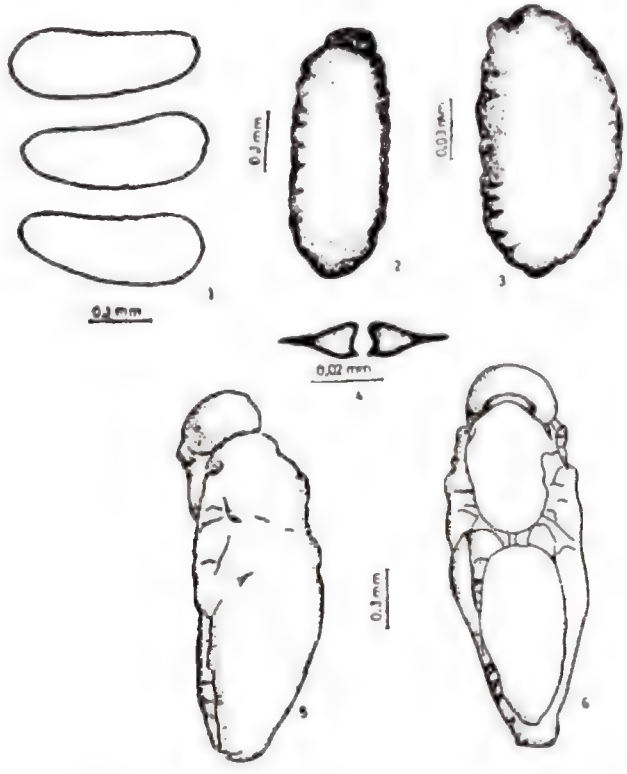

Fig. 1. Developmental stages of *Elasmus brevicornis* Gahan.
1. Egg; 2. 1st instar larva; 3. 3rd instar larva; 4. Mandibles of 3rd instar larva; 5–6. Pupa (lateral and dorsal views).

(*iv*) *Adult:* Female: Body dark in colour. Antennae yellowish brown, 7 jointed; wings hyaline, transparent and hirsute; legs generally hirsute; foreleg femur dark brown at the base, the remaining region tibia and tarsomeres pale and transparent; middle leg more or less like that of foreleg except a major part of the femur is brownish in colour; hind leg femur completely dark brown; tibia and tarsomeres light brownish. Abdomen has thick yellowish brown band in the apical segment and dark in the basal segment.

Male: body colour black; body length, smaller than female and antennae plumose with three of the middle segment developing long flagellate branches.

Life history: *E. brevicornis* is a gregarious ectoparasite which oviposits on the body of the host larva after paralysing it. The duration of the egg stage ranges from 18 to 24 hours.

After hatching the larva attaches itself to the body of the host and begins to feed on the body fluids. The larval period is very brief and ranges from 3 to 4 days. By the time the parasite larvae are full grown only the exuviae and the head capsule of the host remains. The full grown larvae move away from the body of the host and after casting the meconium enter the prepupal stage. This stage is transluscent green in colour and lasts for average of 1.12 days (range 1–2 days). The pupal period lasts for 4 to 6 days.

The total period of life cycle from egg to adult emergence ranges from 9 to 14 days. Relatively few biological studies have been made on the other species of this family. RAMACHANDRA-RAO & CHERIAN (1927) studied the morphology of *E. nephantidis* Roh. a parasite of the coconut caterpillar, *Opisina arenosella* in India. The life cycle of Elasmidae appears to be consistently very short. Development from deposition of the egg to the emergence of adults required 10–16 days for *E. nephantidis* and an average of 14.5 days for *E. hispidarum* at a mean temperature of 29°C (TAYLOR, 1937).

Mating occurs soon after emergence. When a male encounters a female it stops for a while then mounts the female from the rear and moves up to the thoracic region until its head is in line with that of the female. At this stage the female stops moving. Then the male moves its head up and down in quick jerks. The antennae are curved forward and brush the antennae of the female in a vibrating motion. This activity continues for 5 to 10 minutes. In 9 out of 10 cases the female became restless and impatient and brushed the male off with its hind legs or tried to move about until eventually the male is dislodged. Only in one out of ten cases, the male after the initial courtship activity moved backwards and thrust the top of its abdomen beneath the female and copulated. Mating lasts for about 15 seconds. The male then moves off and both groom themselves.

Oviposition:

Females commence oviposition on the day of emergence. They select larvae that have formed a silken web in the leaf for feeding. After locating the preferred stage the female inserts the ovipositor through the web and quickly stings the larva. The larva is completely paralysed and assumes a twisted and flaccid condition. The female places its eggs on the body of the completely paralysed larva. Frequently host larvae are paralysed but no eggs are laid. Paralysed larvae do not regain their mobility.

The average number of eggs laid on each host is 13.68 (range 7–15) and out of this on an average 8.60 adults emerged. The

number of individuals which develop to maturity upon a single host is much greater in other species. CHERIAN & ISRAEL (1937) reared a maximum of 170 adults of *E. zehntneri* Ferr. from a single caterpillar of *Topa-utes* sp. (average. 75).

Host age preference for oviposition: Maximum parasitism (32.80%) was recorded in the third instar larva and 9.0% for the second instar larava. The first, fourth and fifth instars were not attacked. In *E. hispidarum* oviposition occurred on all stages of the host larva (TAYLOR, 1937) while the prepupal stage of *Opisina aresonella* found in a web was preferred for oviposition by *E. nephantidis* (RAMACHANDRA-RAO & CHERIAN, 1927).

Sex ratio:

The sex ratio of 126 field collected pupae was determined to be 1:4.8 in favour of females.

Fecundity: The experiment conducted to study the fecundity of *E. brevicornis* revealed that the number of eggs laid by a female ranged from 21–68 (average 42.70) during a period of 9–12 days. In *E. nephantidis* the number of eggs recorded for a single female varied from 14 to 57 (RAMACHANDRA-RAO & CHERIAN, 1927).

Longevity:

When fed on 20% honey solution females of *E. brevicornis* lived an average of 14.65 days (range 11–25 days); mean longevity of males was 12.05 days (range 9–15 days) (n=20). Without food or water both sexes died within 2 to 3 days. RAMACHANDRA-RAO & CHERIAN (1927) recorded that the maximum longevity for *E. nephantidis* adults was 20 days.

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PROTEOLYTIC ACTIVITY OF GUT HOMOGENATE OF THE KOLA WEEVIL, *SOPHRORHINUS INSPERATUS* FAUST

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Studies on the properties of proteases present in the gut extract of the kola weevil, *Sophrorhinus insperatus* reveal that the proteolytic activity is most active at 45°C while the optimum pH was found to be 10.0. Both trypsin-like and chymotrypsin-like enzymes were detected in the gut of the weevil but tryptic activity constitutes the major endopeptidase. Fourteen protein bands were resolved by polyacrylamide gel electrophoresis. Possible physiological significance of these properties are considered and compared with other insect proteases.

(*Key words*: protease, gut, *Sophrorhinus insperatus*, electrophorosis)

INTRODUCTION

The kola weevil, *Sophrorhinus insperatus* Faust is a serious storage pest of *Cola nitida* (Vent) Schott and Endlicher in West and Central Africa. Weevil infestation starts from the field and it is carried into storage where the insect continues its destructive activities (GERARD, 1967; DARAMOLA, 1978).

Proteolytic enzymes have been examined by many workers and their presence demonstrated in many insects (DADD, 1956; BIRK *et al.*, 1962; APPLEBAUM *et al*, 1964; GOODING & HUANG 1969; BAKER, 1976). Comprehensive reviews on this subject have been undertaken by GOODING (1972), HOUSE (1974) and APPLEBAUM (1985). Since nuts of *Cola nitida* contain about 8% crude protein (OGUTUGA, 1975), one expects some degree of proteolytic activity in the weevils that attack them.

This paper reports studies on the nature of digestive proteases in the gut of the kola weevil, *Sophrorhinus insperatus*.

MATERIALS AND METHODS

Insect culture: New generations of adult *Sophrorhinus insperatus* were reared from the field of infested kola nuts according to the method described by DARAMOLA (1978).

Preparation of gut homogenate: Whole guts of adult weevil were carefully dissected out in ice-cold distilled water and homogenized in 0.5 ml of same in an all-glass homogenizer. The homogenate was adjusted to 4 guts/ml and centrifuged at 4,000 rev/min for 5 minutes. The supernatant was dialysed against a large volume of distilled water for 16 hours at 4°C. The dialysed extract was re-centrifuged at 5,000 rev/min for 10 minutes. The resulting supernatant was used as enzyme extract without further purification.

Determination of enzymatic activity: Proteolytic activity in the gut preparation was determined according to the methods of RINDERKNECHT *et al.* (1968) as described by BRIEGEL & LEA (1975). The reaction mix-

ture comprised 20 mg of hide powder azure, 2.0 ml phosphate buffer, pH 10.0 and 0.5 ml of enzyme solution. Incubation was for forty minutes in a thermostatically controlled water bath which was agitated manually at regular intervals. The reaction was terminated by addition of 3.0 ml ice-cold carbonate buffer (pH 10.0) to the reaction mixture and samples were immediately percolated through a Whatman No. 1 filter paper. The absorbance of the filtrate was read on a CE 343 single sample spectro-photometer at 595 nm. All assays were carried out in triplicates.

The buffer systems used to determine the effect of variation of pH on the hydrolysis of hide powder azure were acetate, pH 5.0–5.5; phosphate, pH 6.0–8.0 and pH 11.0–11.5; borate, pH 8.5–9.5; carbonate, pH 10.0–10.5 and hydroxide – chloride pH 12.0 –12.5.

Variation of proteolytic activity with incubation period at 10 minutes interval for 60 minutes was investigated while the effect of enzyme concentration on enzymatic activity was assayed in reaction mixtures containing 1, 2, 4, 6, 8 and 10 guts/ml of distilled water.

The effect of temperature on proteolytic activity was investigated between 25°C and 60°C at 5°C increment in temperature. The combined effects of incubation temperature and time was tested at 30°C, 40°C and 50°C respectively at regular intervals of fifteen minutes.

Investigation on the variation of protease activity with varying concentrations of hide powder azure was assayed in reaction mixtures containing between 10 and 30 mg of hide powder azure per 2.0 ml of carbonate buffer.

Electrophoresis: Electrophoretic studies of the whole gut extract were carried out in 12.5% polyacrylamide gel prepared according to WEBBER & OSBORN (1975). The resulting protein bands were characterised with tosyl-L-arginine methyl ester (TAME) and Benzoyl-L-tyrosine ethylester (BTEE) as specified by HUMEL (1959). Tryptic activity was also determined according to the procedure of SCHWET & TAKENAKA (1955) by employing alpha-N-benzoyl-L-arginine ethyl ester (BAEE) as substrate.

RESULTS

An approximately linear relationship was obtained over a sixty-minute incubation period thus indicating the stability of the enzymes at the described reaction conditions (Fig. 1). A digestion period of forty minutes was therefore adopted for most of the subsequent experiments since this incubation period fitted perfectly well into the linear phase of the enzymatic curve.

A linear relationship was obtained upto 10 guts/ml phosphate buffer (Fig. 2).

The pH-activity curve of the proteolytic enzymes present in the gut extract of the adult *S. insperatus* is given in Fig. 3. The enzymes were active between pH 5.5 and 12.5. The curve also showed that considerable activity was obtained between pH 8.0 and 12.0. Two distinct peaks were obtained for the pH-profile, one major peak at pH 10.0 and a minor one at pH 11.5.

The hydrolysis of varying concentrations of hide powder azure by the gut proteolytic enzymes of the kola weevil showed an initially linear relationship upto 20 mg/ml of hide and powder azure (Fig. 4). However, the rate of hydrolysis was no longer directly proportional to the substrate concentration above this concentration.

The temperature-response to gut proteolytic activity of the kola weevil is shown in Fig. 5. A single symmetrical curve was obtained with optimum activity at 45°C. Enzymatic activity decreased on either side of the optimum temperature. However, the bulk of the enzyme activity was obtained between 30°C and 50°C. The result of the combined effect of temperature and incubation time on enzymatic activity, (Fig. 6) suggests that the optimum activity of the enzyme is a combined function of its incubation period and that of incubation temperature. At 15-minute incubation period, an optimum temperature of 50°C was obtained whereas 40°C was found to be optimum when the reaction mixture was incubated for 90 minutes.

The gut homogenate of the adult *S. insperatus* was resolved into fourteen protein bands (Fig. 7) by polyacrylamide gel electrophoresis. Bands 1 and 2 which were fast moving

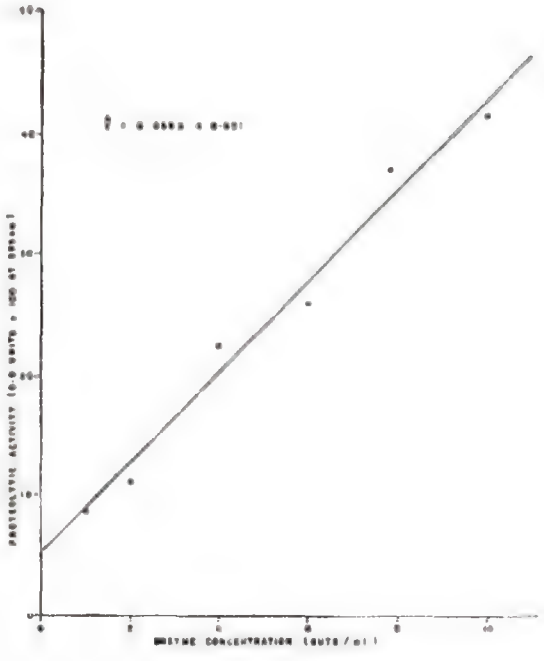

Fig. 2. Effect of enzyme concentration on the proteolytic activity of the gut enzyme extract of adult *S. insperatus.*

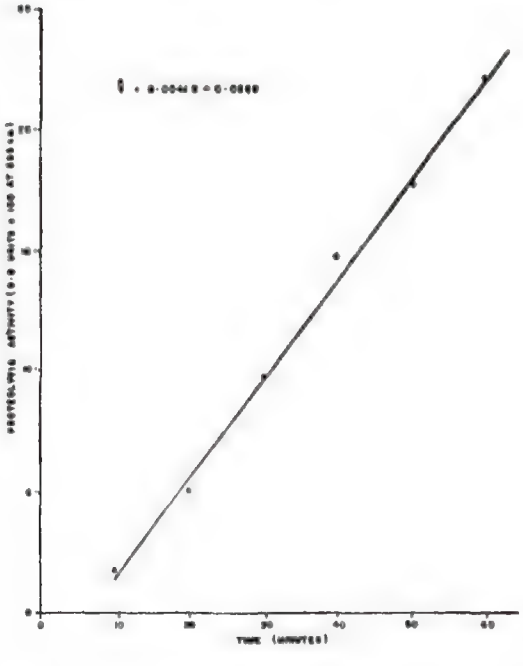

Fig. 1. Time-proteolytic activity curve for the gut enzyme extract of adult *S. insperatus.*

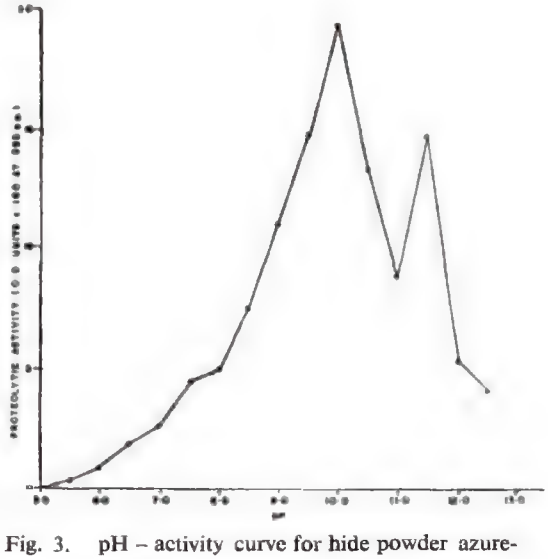

Fig. 3. pH – activity curve for hide powder azure-hydrolysis by the gut enzyme extract of adult *S. insperatus.*

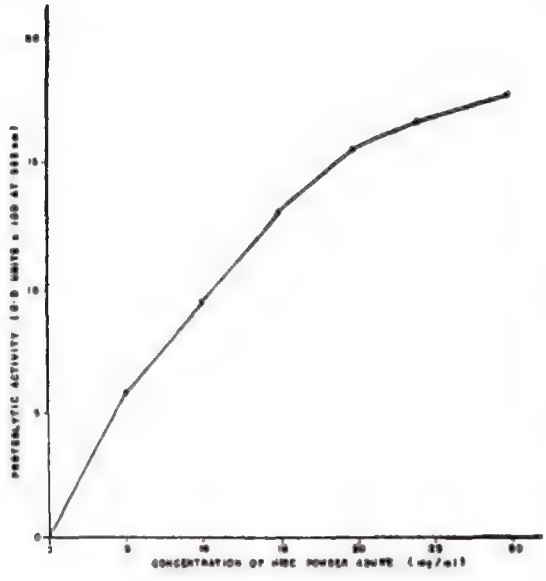

Fig. 4. The effect of protein concentration (sub strate) on the proteolytic activity of the gut enzyme extract of adult *S. insperatus.*

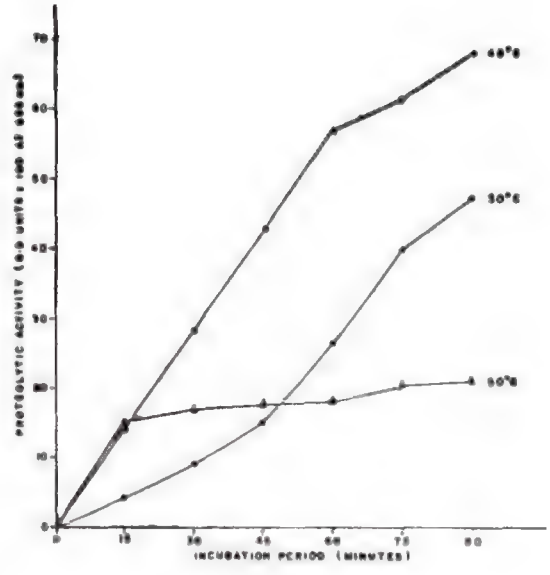

Fig. 6. Combined effect of temperature and incubation period on proteolytic activity ol the gut extract of adult *S. insperatus.*

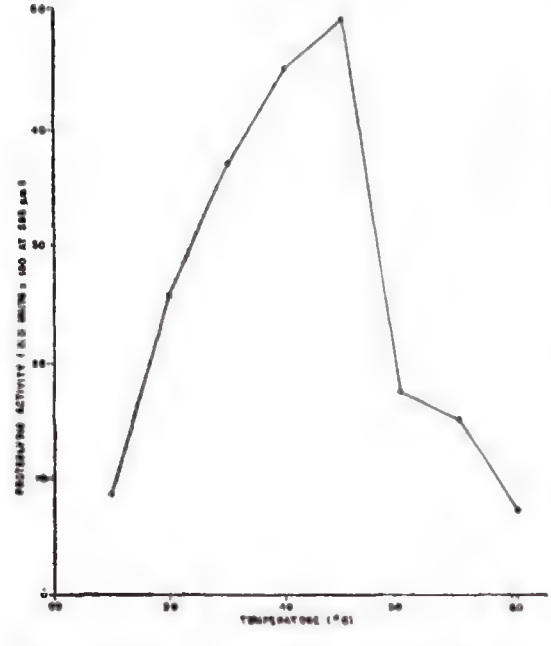

Fig. 5. Effect of temperature on proteolytic activity of the gut enzyme of adult *S. insperatus.*

anodal components exhibited high affinity towards TAME and BAEE thus indicating the presence of trypsin-like enzyme. The trypsin-like enzyme of this weevil has more affinity for TAME than BAEE. Slight hydrolysis of TAME was also observed in bands 2, 3 and 4 while bands 3, 4 and 5 hydrolysed BAEE partially. Bands 1 and 4 hydrolysed BTEE slightly thus suggesting the presence of chymotrypsin-like enzyme. In all the cases tryptic activity was consistently higher than chymotryptic activity.

DISCUSSION

The pH-profile for the proteolytic activity of adult *S. insperatus* indicates that the alimentary canal of adult *S. insperatus* contains general proteolytic enzymes with optimum activity in the high alkaline range which is similar to those of many insect species (SHARMA et al., 1984). The two peaks observed in the pH-activity curve sug-

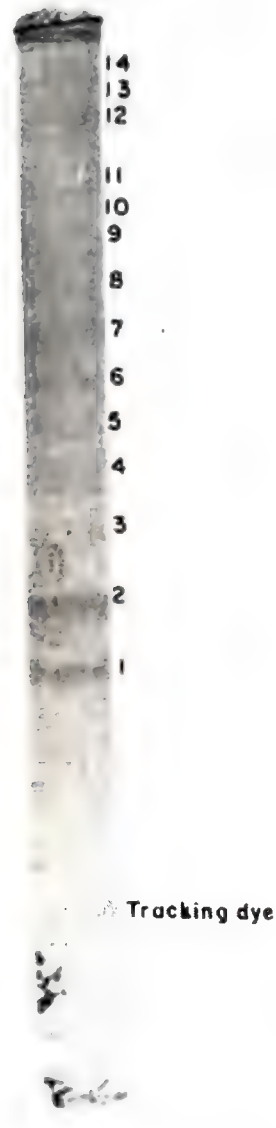

Fig. 7. Electropherogram of the proteins in the whole gut extract of the adult *Sophrorhinus insperatus* Faust.

gest the presence of a strongly alkaline proteinase with double maxima. Broadly, digestive proteinases in insect guts are more active in the neutral or alkaline range (DADD, 1970; HOUSE, 1974). However, acid proteinases have been reported mainly in dipterous insects (GOODING, 1969; PENDOLA & GREEN, 1975; HOUSEMAN & DOWNE, 1982) and in some Coleopterous species (BAKER, 1982). Enzymatic activity was extremely low at pH 5.5 with about 98% of the total activity suppressed, thus suggesting the absence of pepsin-like enzyme. Similar observations have been reported for the sweet potato weevil, *Cylas formicarius elegantulus* (Summers) (BAKER *et al.*, 1984) where activity towards hide powder azure was optimum between pH 9.0 and 11.5. The midgut homogenate of *Attagenus megatoma* contained only alkaline proteinase (BAKER, 1976) whereas some *Sitophilus* species exhibited both acid and alkaline proteinases with a minor peak between pH 3.0 and 4.0 while the major peak was at pH 10.0 (BAKER, 1982).

The results presented in Fig. 5 suggest that the optimum temperature for the activity of the proteolytic enzymes in the alimentary canal of adult *Sophrorhinus* is 45°C. This optimum temperature is comparable to those of other insect species reported by EVANS (1958), BAKER (1976) and MUSE (1984). In *S. insperatus* optimum temperature for the gut proteolytic enzymes was altered by variation in incubation time. Similar observations have been reported for *Zonocerus variegatus* L (OLADAPO, 1979) and *Chrysomyia chloropyga* by MUSE (1984). Relatively high optimal temperature and heat stability status of the proteolytic enzymes of *S. insperatus* are typical of insects living in tropical and sub-tropical regions.

An initially linear relationship between hide powder azure concentration and protease activity was obtained upto substrate concentration of 20 mg/ml but the magnitude of the increase in enzyme activity reduced after this concentration. This is possibly due to saturation of the enzyme by the substrate which is a common phenomenon for many proteases (ISHAAYA *et al.* 1970; BAKER, 1976; GOODING & ROLSETH, 1976; OLADAPO, 1979). The relationship between substrate concentration and proteolytic activity in *Sophrorhinus* is similar to what were obtained for other insect proteases (BAKER, 1976; GOODING & ROLSETH, 1976).

Fourteen protein bands were discernible when whole gut homogenate of *S. insperatus* adults was analysed by polyacrylamide gel electrophoresis thus suggesting the heterogeneity of proteins in the gut homogenate. The fastest moving protein band, which was also a major band, exhibited the highest activity towards TAME and BAEE thus indicating the presence of trypsin-like enzyme. The enzyme affinity to TAME was much higher than towards BAEE probably suggesting TAME as a better substrate for the enzyme. These results tend to agree with HUMMEL's (1959) generalization that the fast moving anodal protein bands often exhibit tryptic activity.

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PERFORMANCE OF DIFFERENT BREEDS OF SILKWORM *BOMBYX MORI* L. AND THEIR HYBRIDS FOR PUPAL AND ALLIED TRAITS

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Among six parental silkworm breeds, their 13 single and 16 three-way cross hybrids, the bivoltine breed 'KA' and bivoltine single cross hybrids 'NB_{18}' × 'Saniish-$_{18}$' and 'NB_{18}' × 'J_{122}' exhibited superiority for three economic traits out of five traits. Out of five poly × bivoltine hybrids, 'C. Nichi' × 'KA' and 'C. Nichi' × 'NB_{18}', showed superiority for hatching. The three-way crosses 'C. Nichi' × ('J_{122}' × 'NB_{18}'), C. Nichi' × ('NB_{18}', × 'J_{122}'), 'C. Nichi' × ('KA' × 'NB_7') and ('NB_{18}' × 'Saniish-$_{18}$') × 'C. Nichi' performed superb for fecundity and hatching.

(*Key words*: *Bombyx mori*, hybrids, performance)

INTRODUCTION

India ranks third among the leading mulberry silk producing countries. Karnataka stands first by contributing 59 percent of total raw silk production in the country. During VII plan, our country requires 30 crores of disease free layings but the percent production is only 10 crores (NARASIMHANNA, 1985). At present a large number of hybrid combinations with multivoltine × bivoltine breeds are being reared in various parts of the country. In spite of recent introduction of superior bivoltine breeds, there still exists a preference to old races like 'C. Nichi' among the sericulturists. The present study is thus an attempt to know the quantitative aspects concerned with pupal and related traits in pure breeds of silkworm *Bombyx mori* L. as well their single and three-way cross hybrids.

MATERIALS AND METHODS

A polyvoltine breed 'C. Nichi' and five bivoltine breeds namely 'Saniish–$_{18}$' (SH), 'J_{122}' (J), 'Kalimpong–A' (KA), 'NB_{18}' and 'NB_7' were utilized as parental breeds in this study. Five poly × bivoltine and eight bi × bivoltine single and eight each of direct and reciprocal three-way crosses were prepared (Table 1). The hybrids along with parents were reared twice during January to April 1987. Three replications were maintained for each. A single disease free laying formed a replication. The standard method for young and late age silkworm rearing was practised as recommended by KRISHNASWAMI (1978, 1979).

Data collected on five pupal traits from both the rearings were pooled together and analysed by the methods or SNEDECOR & COCHRAN (1979).

RESULTS AND DISCUSSION

The results pertaining to five pupal and allied traits are presented in Table 1 and the same are discussed hereunder.

Pupal weight:

The bivoltine single cross hybrids 'Saniish –18' × 'NB_{18}' (16.90g), 'NB_{18}' × 'Sannish–18' (16.74 g), 'NB_{18}' × 'J_{122}' (16.11g) and parent 'KA' (16.65g) registered maximum weight for 10 pupae. It was minimum in

TABLE 1. Performance of different silkworm breeds and hybrids for pupal and allied traits.

Sl. no.	Breeds/hybrids	Weight of 10 pupae (g)	Pupal duration (h)	Moth emergence (%)	Fecundity (eggs/ laying)	Hatching (%)
1	2	3	4	5	6	7
1	'CN'	10.57	244	97 (80)*	334	93 (75)*
2	'SH'	13.36	305	96 (79)	475	91 (73)
3	'J'	12.30	288	97 (80)	486	95 (77)
4	'KA'	16.65	257	96 (79)	516	93 (75)
5	'NB18'	12.49	285	96 (79)	513	94 (76)
6	'NB7'	13.67	314	94 (76)	566	93 (69)
7	'SH' x 'J'	15.18	312	98 (81)	522	90 (72)
8	'J' x 'SH'	15.96	320	91 (73)	602	97 (80)
9	'SH' x 'NB18'	16.90	297	96 (79)	564	93 (74)
10	'NB'18 x 'SH'	16.74	295	94 (76)	608	94 (76)
11	'J' x 'NB18'	15.54	297	96 (79)	584	94 (76)
12	'NB18' x 'J'	16.11	300	94 (76)	592	96 (78)
13	'KA' x 'NB7'	14.80	344	98 (82)	564	93 (74)
14	'NB7' x 'KA'	15.95	333	99 (83)	553	96 (79)
15	'CN' x 'SH'	11.45	253	88 (70)	499	88 (70)
16	'CN' x 'J'	14.34	276	95 (77)	426	88 (70)
17	'CN' x 'KA'	15.47	279	95 (76)	551	93 (74)
18	'CN' x 'NB18'	15.45	263	96 (79)	493	94 (76)
19	'CN' x 'NB7'	15.09	265	93 (74)	575	91 (72)
20	'CN' x ('SH' x 'J')	14.69	275	89 (71)	557	92 (74)
21	'CN' x ('J' x 'SH')	15.45	277	88 (70)	581	87 (68)
22	'CN' x ('SH' x 'NB'18)	14.87	287	92 (78)	508	92 (74)
23	'CN' x ('NB'18 x 'SH')	14.81	274	97 (81)	588	86 (68)
24	'CN' x ('J' x 'NB'18)	14.46	275	95 (77)	612	88 (70)
25	'CN' x ('NB18' x 'J')	14.25	272	96 (79)	593	96 (78)
26	'CN' x ('KA' x 'NB7')	15.08	276	94 (75)	612	93 (75)
27	'CN' x ('NB7' x 'KA')	14.52	277	97 (80)	546	92 (73)
28	('SH' x 'J') x 'CN'	14.07	297	92 (74)	490	90 (72)
29	('J' x 'SH') x 'CN'	14.34	287	89 (71)	634	89 (71)
30	('SH' x 'NB18') x 'CN'	13.43	288	96 (79)	593	94 (75)
31	('NB'18 x 'SH') x 'CN'	13.80	288	96 (79)	605	93 (75)
32	('J' x 'NB18') x 'CN'	13.29	288	93 (75)	514	91 (73)
33	('NB'18 x 'J') x 'CN'	14.02	287	95 (77)	542	93 (75)
34	('KA' x 'NB7') x 'CN'	13.80	301	94 (76)	574	93 (74)
35	('NB7' x 'KA') x 'CN'	14.25	286	89 (71)	517	88 (70)
	S Em ±	0.45	8.02	0.89	21.82	2.32
	C D at 5%	0.87	15.73	1.74	42.77	4.54

* Figures in parentheses are angular transformed values.

'C. Nichi (10.57g). None of the multi × bi single and three-way crosses showed superiority for this trait.

Pupal duration:

The parent 'C. Nichi' registered minimum pupal period of 244 h which did not deviate that of 'C. nichi' × 'Saniish–18' (253 h) and 'KA' (257 h). Maximum pupal period was recorded in 'KA' × 'NB_7' (344 h) and its reciprocal cross (333 h) (Table 1). The variation may be due to their ability to combine for this trait and genetic architecture.

Moth emergence:

Maximum moth emergence was achieved in bivoltine single cross 'NB_7' × 'KA' (99%) along with 'KA' × 'NB_7', 'Saniish–18' × 'J_{122}', and a three-way cross hybrid 'C. Nichi' × ('NB_{18}' × 'Saniish–$_{18}$') and a bivoltine parent 'J_{122}' (97 to 98%) (Table 1). BENCHAMIN & KRISHNASWAMI (1981) reported maximum moth emergence in 'NB_7'- (87%) and 'NB_{18}' (88.6%) among bivoltine breeds.

Fecundity:

The reciprocal three-way cross 'J_{122}' × 'Saniish–18') × 'C. Nichi' (634) registered the highest number of eggs per laying along with three bivoltine single cross hybrids viz., 'J_{122}' × 'Saniish–18', 'NB' × 'Saniish–18' and 'NB_{18}' × 'J_{122}' and five three-way cross hybrids, namely 'C. Nichi' × (Saniish–18') × 'J_{122}'), 'C. Nichi' × ('J_{122} × NB_{18}'), (C. Nichi' × (NB_{18}' × 'J_{122}'), 'C. Nichi' × ('KA' × NB_7') and ('NB_{18}' × 'Saniish18') × C. Nichi' (592 to 612) (Table 1). The minimum fecundity was encountered in 'C. Nichi' (334). The high egg production in multi × bivoltine single and three-way crosses and their reciprocals has been reported (ANONYMOUS, 1982)

Hatching:

Maximum hatching was found in single cross hybrid 'J_{122}' × 'Saniish–18' (97%) which was on par with five parental breeds, six multi × bi and two bi × bivoltine single and seven three-way crosses. Minimum of 86 percent hatching was observed in 'C. Nichi' × ('NB_{18}' × 'Saniish–18'), two single and six three-way crosses. These observations are comparable with those of TIKOO *et al.* (1971) who reported no significance in hatching percentage among multi × bivoltine single cross hybrids.

In the current investigation a parental breed 'Kalimpong–A' and two bivoltine single cross hybrids 'NB_{18}' × 'Saniish–18' and 'NB_{18}' × 'J_{122}' exhibited superiority for three quantitative traits out of five traits experimented. Amongst multi × bivoltine hybrids, 'C. Nichi' × 'KA' and 'C. Nichi' × 'NB_{18}' marked superiority for hatching. The three-way cross hybrids namely 'C. Nichi' × ('J_{122}' × 'NB_{18}), 'C. Nichi' × (NB_{18}' × 'J_{122}') 'C. Nichi' × ('KA × NB_7') and ('NB_{18}' × 'Saniish–18') × 'C. Nichi' registered superiority for fecundity and hatching. To meet the high demand of eggs, the moths of already available desirable bivoltine single cross hybrids can be effectively utilized for producing three-way cross hybrid eggs which can be distributed to sericulturists for commercial cocoon production, thereby the cost of egg production can be cut down to considerable extent without sacrificing the quantitative traits. The other advantages of three-way crosses are high fecundity and ease of rearing. Considering all the above points, the specific combinations of bivoltine hybrids and three-way cross hybrids can be made available to the rearers so that scarcity of eggs can be overcome.

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PERFORMANCE OF SOME SINGLE AND THREE-WAY CROSS HYBRIDS OF SILKWORM *BOMBYX MORI* L. FOR LARVAL TRAITS

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Among 13 single and eight each of direct and reciprocal three-way cross hybrids, the bivoltine single cross hybrid 'NB'$_{18}$ × 'J$_{122}$' was superior for larval weight before settling for third moult and maximum larval weight. The three-way cross hybrid ('Kalimpong–A' × 'NB$_7$') × 'Pure Mysore' gave significantly higher values for percent progression to fourth instar, larval duration and effective rate of rearing. In general the three-way crosses were found to possess less larval duration.

(*Key words*: silkworm, *Bombyx mori*, hybrids)

INTRODUCTION

Southern India enjoys favourable climatic conditions throughout the year both for mulberry cultivation and silkworm rearing. At present multivoltine × bivoltine and bi × bivoltine single cross hybrids are largely used for commercial silk production. The multivoltine breed 'Pure Mysore' is known to be more resistant to diseases and produces less silk of poor quality. The bivoltine breeds are known to give good yields. There exists little literature on the performance of 'Pure Mysore' × bivoltine breeds and so also on the three-way cross hybrids in Northern Karnataka. In view of the above, the present study is an attempt to generate information on the performance of single and three-way cross hybrids.

MATERIALS AND METHODS

A multivoltine breed 'Pure Mysore' (PM) and five bivoltine breeds viz., 'Saniish–18' (SH), 'J$_{122}$' (J), 'Kalimpong–A' (KA), 'NB$_{18}$' and 'NB$_7$', were the parental breeds using which 13 single and eight each of three-way direct and reciprocal crosses were prepared (Table 1). One disease free laying was maintained for each of the three replications. The rearing was conducted by adopting the standard procedure advocated by KRISHNASWAMI (1978, 1979). Data recorded on larval weight before settling for third moult, percent progression to fourth instar, maximum larval weight, larval duration and effective rate of rearing were analysed by following the method of SNEDECOR & COCHRAN (1979).

RESULTS AND DISCUSSION

The results of the study are discussed below under each character.

Larval weight before settling for third moult:

Larval weight before settling for third moult is one of the important characters indicating the robustness of the silkworm in early instars. The bivoltine single cross hybrids 'J' × 'NB'$_{18}$ (1.97 g), 'J' × 'SH' (1.93 g) and 'NB'$_{18}$ × 'J' (1.91 g) exhibited significantly highest values. All the multivoltine × bivoltine and three-way cross hybrids comparatively recorded less weight (Table 1).

TABLE 1. *Per se* performance of parental breeds and hybrids of silkworm for larval traits.

Sl. no.	Breeds/ hybrids	Larval weight before settling for third moult (g) 10 worms	Progression to fourth instar (%)	Maximum larval weight (g)/ 10 worms	Larval duration (h)	Effective rate of rearing (%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	'PM'	0.615	83.80 (66.27)*	19.65	719	90.20 (71.78)*
2.	'SH'	1.55	79.40 (63.02)	40.53	705	85.80 (67.88)
3.	'J'	1.57	85.00 (67.19)	34.34	648	83.60 (66.10)
4.	'KA'	1.73	82.90 (65.57)	43.44	682	91.10 (72.69)
5.	'NB18'	1.64	82.50 (65.27)	38.64	690	85.90 (67.90)
6.	'NB7'	1.50	79.90 (63.34)	38.34	675	86.80 (68.73)
7.	'SH' x 'J'	1.63	84.90 (67.14)	43.91	646	90.20 (71.75)
8.	'J' x 'SH'	1.93	88.20 (69.94)	45.34	626	91.50 (73.09)
9.	'SH' x 'NB18'	1.76	90.90 (72.41)	46.70	651	91.60 (73.11)
10.	'NB'18 x 'SH'	1.90	88.70 (70.33)	45.39	654	91.30 (72.81)
11.	'J' x 'NB18'	1.97	87.00 (68.86)	45.61	650	88.70 (70.35)
12.	'NB'18 x 'J'	1.91	85.30 (67.42)	48.32	647	91.90 (73.48)
13.	'KA' x 'NB7'	1.66	83.90 (66.30)	43.99	668	90.00 (71.59)
14.	'NB7' x 'KA'	1.91	82.60 (65.37)	44.35	670	93.10 (74.79)
15.	'PM' x 'SH'	1.04	89.90 (71.42)	32.29	611	92.10 (73.69)
16.	'PM' x 'J'	1.16	87.80 (69.51)	38.80	587	93.70 (75.49)
17.	'PM' x 'KA'	1.11	89.90 (71.47)	35.69	610	94.30 (76.11)
18.	'PM' x 'NB'18	1.13	90.20 (71.76)	36.54	612	94.70 (76.79)
19.	'PM' x 'NB'7	1.08	84.20 (69.54)	36.41	610	93.50 (75.24)
20.	'PM' ('SH x 'J')	1.14	91.30 (72.85)	37.37	600	93.80 (75.51)
21.	'PM' ('J' x 'SH')	1.13	90.30 (71.82)	37.31	599	92.50 (74.17)
22.	'PM' ('SH' x 'NB18')	1.18	88.10 (69.83)	38.40	610	95.20 (77.37)
23.	'PM' ('NB'18 x 'SH')	1.14	90.00 (71.56)	35.66	598	92.00 (73.55)
24.	'PM' ('J' x 'NB18')	1.19	86.90 (68.77)	38.67	598	96.30 (78.99)
25.	'PM' ('NB'18 x 'J')	1.11	89.20 (70.83)	38.57	598	92.40 (74.07)
26.	'PM' ('KA'x 'NB7')	1.01	88.00 (69.76)	33.27	610	93.90 (75.72)
27.	'PM' ('NB7' x 'KA')	1.13	87.60 (69.35)	38.76	597	94.10 (75.99)
28.	('SH' x 'J') 'PM'	1.24	87.30 (69.16)	34.45	542	92.40 (73.98)
29.	('J' x 'SH') 'PM'	1.26	89.10 (70.72)	35.43	594	96.20 (78.77)
30.	('SH' x 'NB18') 'PM'	1.20	90.20 (71.79)	34.92	593	94.40 (76.29)
31.	('NB18' x 'SH') 'PM'	1.20	88.70 (70.31)	34.20	598	93.30 (75.04)
32.	('J' x 'NB'18) 'PM'	1.27	88.60 (70.29)	33.50	597	94.60 (76.61)
33.	('NB'18 x 'J') 'PM'	1.22	88.70 (70.31)	34.46	549	92.20 (73.75)
34.	('KA' x 'NB7') 'PM'	1.14	89.90 (71.43)	32.59	542	96.50 (79.22)
35.	('NB'7 x 'KA') 'PM'	1.17	91.50 (73.05)	32.79	587	93.90 (75.78)
	S Em ±	0.031	1.018	0.669	1.300	1.038
	C D at 5%	0.062	1.996	1.312	2.548	2.035

*Figures in parentheses are angular transformed values.

Percent progression to fourth instar:

The three-way reciprocal hybrid ('NB_7' × 'Kalimpong–A') × 'Pure Mysore' (91.50%) gave the highest percent of progression to fourth instar. It was followed by 'Pure Mysore' × ('Saniish–18' × 'J_{122}') (91.30%), 'Saniish–18' × 'NB'_{18} (90.90%), 'Pure Mysore' × ('J_{122}' × 'Saniish–18') (90.30%), ('Saniish–18' × 'NB'_{18}), × 'Pure Mysore' (90.20%), 'Pure Mysore' × 'NB'_{18} (90.20%), 'Pure Mysore' × ('NB'18 × 'Saniish–18') (90 00%), 'Pure Mysore' × 'Kalimpong–A' (89.90%), ('Kalimpong–A' × 'NB_7') × 'Pure Mysore' (89.90%) and 'Pure Mysore' × 'Saniish–18' (89.90%). The literature pertaining to this parameter is very little. This may have to be considered as one of the important traits as it has a direct bearing on the survival and effective rate of rearing to a considerable extent. It will also further indicate the healthiness of silkworms in early instars.

Maximum larval weight:

The maximum larval weight for 10 worms was highest in 'NB'_{18} × 'J'_{122} (48.32g) (Table 1). The values of 'Saniish–18' × 'NB'_{18} (46.70 g), 'J_{122}' × 'NB'_{18} (45.61 g) and 'NB'_{18} × 'Saniish–18' (45.39 g) are also comparable with that of 'NB'_{18} × 'J_{122}'. However lower weight was observed among multivoltine × bivoltine and three-way cross hybrids.

Larval duration:

Larval duration was shorter observed in three-way cross hybrids. The crosses ('Kalimpong–A' × 'NB_7' × 'Pure Mysore' (542 h) and ('Saniish–18' × 'J_{122}') × 'Pure Mysore' (542 h) resulted in less larvl duration. This observation is in agreement with previous report (ANONYMOUS, 1982). The 'Pure Mysore' parental breed recorded the maximum larval duration of 719 h. KRISHNASWAMI & TIKKOO (1971) also reported larval duration of 736 h in 'Pure Mysore'.

Effective rate of rearing (*ERR*):

The three-way cross and multivoltine × bivoltine single cross hybrids yielded the highest E.R.R. ('Kalimpong–A' × 'NB'_7) × 'Pure Mysore' (96.50%), 'Pure Mysore' × ('J_{122}' × 'NB_{18}') (96.30%), ('J_{122}' × (Saniish-$_{18}$') × 'Pure Mysore' (96.20%), 'Pure Mysore' ('Saniish–18' × 'NB18') (95.20%) and ('J_{122}' × 'NB_{18}') × 'Pure Mysore' (94.60%) were best among the three-way crosses. This is in conformity with the previous observations (ANONYMOUS, 1975; NARASIMHANNA *et al.*, 1976). The highest E.R.R. in three-way cross hybrid ('K_4' × 'K_1'). That has been reported by PANNENGPET (1973). The multivine × bivoltine single cross hybrid 'Pure Mysore' × 'NB'_{18} (94.70%) also gave the significantly highest E.R.R.

From the foregoing results and discussion, it is obvious that the bivoltine single cross hybrid 'NB'_{18} × 'J_{122}' was superior for larval weight before settling for third moult and maximum larval weight. The three-way cross hybrid ('Kalimpong–A' 'NB_7') × 'Pure Mysore' exhibited its superiority for percent progression to fourth instar, effective rate of rearing and larval duration. At times of shortage of DFLs, the eggs of specific three-way cross hybrids can be supplied to farmers without sacrificing the cocoon yield contributing parameters.

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OCCURRENCE OF UJI FLY *BLEPHARIPA ZEBINA* (WALKER) ON TASAR SILKWORM *ANTHERAEA PAPHIA* (LINN.) IN KARNATAKA

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In Karanataka, the tasar silkworm *Antheraea paphia* (Linn.) suffered from parasitism. The tasar uji *Blepharipa zebina* (Walker) was observed to be the major larval parasite. The studies made on *B. zebina* are reported, and the consequences of its infestation during fifth instar of the host are analysed and discussed. Moreover, under natural conditions no cross-infestation was observed between *B. zebina* and the mulberry silkworm *Bombyx mori* Linn. in the presence of *A. paphia* worms.

(*Key words*: Tasar silkworm, *Antheraea paphia*, tasar uji fly, *Blepharipa zebina*, parasitoid, parasitism)

INTRODUCTION

The tasar silkworm *Antheraea paphia* (Linn.) (=*Antheraea mylitta*, Drury) (ARORA & GUPTA, 1979) (Lepidoptera : Saturniidae) is one of the four kinds of commercial silkworms. It is being cultured in India in wild and semi-domesticated conditions. Tasar rearing is common in humid and dense tropical forests of the Central Plateau providing a subsidiary occupation to tribals and agricultural labourers. Nearly 40 to 45% of the crop loss is due to depredation by a variety of natural enemies. About 10% of the damage is by the tasar uji fly *Blepharipa zebina* (Walker) (Diptera : Tachinidae) which is a major parasite (JOLLY *et al.*, 1974). This parasite is reported from Assam, Bihar, Kerala, Punjab, Uttar Pradesh – India; Burma; Ceylon; Nepal; Thailand; Formosa; Japan and China (DELEINADO & HARDY, 1977). However, there are no critical reports about the parasites of tasar silkworm from Karnataka, where the latter is being reared on commercial scale under semi-outdoor conditions for several decades.

MATERIALS AND METHODS

212 naturally parasitized *A. paphia* cocoons (Sept.–Oct., 1986 crop) on *Terminalia* trees, collected from the commercial rearings of Basic Tasar Seed Farm, Khanapur (Belgaum District - Karnataka), were cut open and grouped on the basis of number of uji puparia they contained. Search for other parasites was made. With reference to *B. zebina* the number of pierced cocoons, location and the number of emergence holes, percent adult emergence of the parasitoid and extent of uji flies trapped inside or escaped from the host cocoon were noted. Moreover, the occurrence of *B. zebina* in the adjacent mulberry silkworm crops was also verified.

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OBSERVATIONS AND DISCUSSION

The study revealed that the cocoon crop of *A. paphia* was found parasitized by the tasar uji fly *B. zebina*. However, none of the *B. mori* rearings brought in the nearhood of the tasar crop, yielded *B. zebina*. Possibly, therefore, the tasar uji fly *B. zebina* did not cross-infest mulberry silkworms in the presence of *A. paphia* larvae. JOLLY *et al.* (1974) have reported *B. zebina* as a major parasite from the traditional and oak tasar belts of North India.

In the present investigations, only 8 cocoons indicated the solitary infestation by *B. zebina* and 204 cocoons indicated 2 to 52 uji parasite per cocoon (Table 1). If a host contains two or more parasites it is said to be super-parasitized (ALLEE *et al.*, 1959).

Thus, the superparasitism appeared to be more common (Fig. 1). The density of uji maggots per cocoon ranged from 1 to 52 with an average of 14.094. COTES (1896) roughly reported 15 tachinid maggots per tasar worm. There was a wide variation in the density of uji maggots per tasar cocoon (vide Table 1). Perhaps this is due to the differential oviposition by the gravid female uji fly depending on the availability of suitable host and host's health and vigour. Interestingly, irrespective of the density of the uji maggots the final instar worms could spin cocoons. But majority of them could not transform into pupae (Fig. 2). Therefore, it appeared that there was no interrelation between the density of the uji maggots and the cocoon spinning ability of the final instar host. In the present study, whereas 204 cocoons demonstrated the dead host in the prepupal condition (Fig. 2), only 8 cocoons revealed the host in pupal stage (Table 1). Therefore, *B. zebina* is mostly a larval and occasionally a larval-pupal parasite. Whenever the maggots emerged from the host larvae, they made one or more holes on them mostly on their ventrolateral aspects (Fig. 2). Very rarely, some maggots emerged from the host pupa but making a single hole on it. This implied that the parasite preferred the early fifth instar among the available fifth instar worms for oviposition.

Nearly, 76.89% of the collected cocoons were pierced (Table 1). Perhaps the uji maggots emerged from the host cocoon after hardening of the shell were not able to pierce it. Therefore, late infestation by *B. zebina*, if occurred in nature, might not spoil the reelability of the tasar cocoons. From among 163 pierced cocoons, majority of them showed a single hole. Only 2 cocoons had 3 holes and 1 cocoon, 2 holes. About 70.55% of the emergence holes were at the base of the peduncle (Fig. 3) followed by 20.86% in the middle, and 8.59% at the opposite end of the cocoon (Table 2).

Despite the cocoons being pierced, majority of the maggots pupated inside the cocoons. This implied that the maggots emerged later, were either not able to detect the hole, or being negatively phototrophic, preferred to pupate inside the cocoon. The adult emergence for the trapped puparia ranged from 77.19 to 100.00% with an average of 95.63% (Table 1), which fact suggested that such a trapping seldom had any ill effect on the process. The flies that emerged inside the unpierced cocoon might lay eggs on the dead host (Fig. 4). Interestingly, majority of the adult flies (82.05%) escaped out of the cocoon through the hole made earlier by the maggot. Perhaps the better developed sense- and locomotor organs along with positively phototropic nature of the adult flies, might have helped them to detect the hole and escape out. However 17.95% of the adult flies could not escape leading to suicidal reproduction of the parasite. Of course, majority of these trapped adult uji flies came from the unpierced cocoons.

TABLE 1. Extent of infestation, emergence and dispersion of the tasar uji fly *B. zebina* in the field collected cocoons of *A. paphia*.

	Number of uji		Number of adult uji flies	
Puparia cocoon	Infested cocoons	Pierced cocoons	Emerged	Escaped
1	8 (4L + 4P)	0	7	0
2	7 (5L + 2P)	4	13	6
3	12	8	34	24
4	6	5	23	19
5	7	6	35	29
6	8 (7L + 1P)	5	48	30
7	11	11	74	68
8	14	12	99	72
9	4	4	36	33
10	12	10	113	99
11	10	6	95	65
12	6	4	71	48
13	9 (8L + 1P)	8	117	102
14	5	4	67	52
15	13	9	191	132
16	6	6	87	87
17	8	6	134	102
18	5	4	78	63
19	6	4	88	75
20	4	4	80	80
21	8	5	160	105
22	5	5	110	110
23	5	4	100	90
24	5	4	112	96
25	2	2	50	50
26	1	1	26	26
27	1	1	26	26
28	1	1	28	28
29	5	4	145	115
30	3	3	90	90
31	4	2	108	58
32	4	4	128	123
33	1	1	33	33
34	3	3	101	100
36	1	1	35	35
44	1	1	44	29
52	1	1	52	52
Total 2988	212 (204L + 8P)	163 (76.89%)	2838 (94.98%)	2352 (82.88%)
Mean 14.094		82.79	95.62	82.05
Variance 87.415		0.0672	0.0198	0.0695
S D 9.34		0.2592	0.1407	0.2636

L or other unspecified number : Host death in prepupal stage. P : Host death in pupal stage.

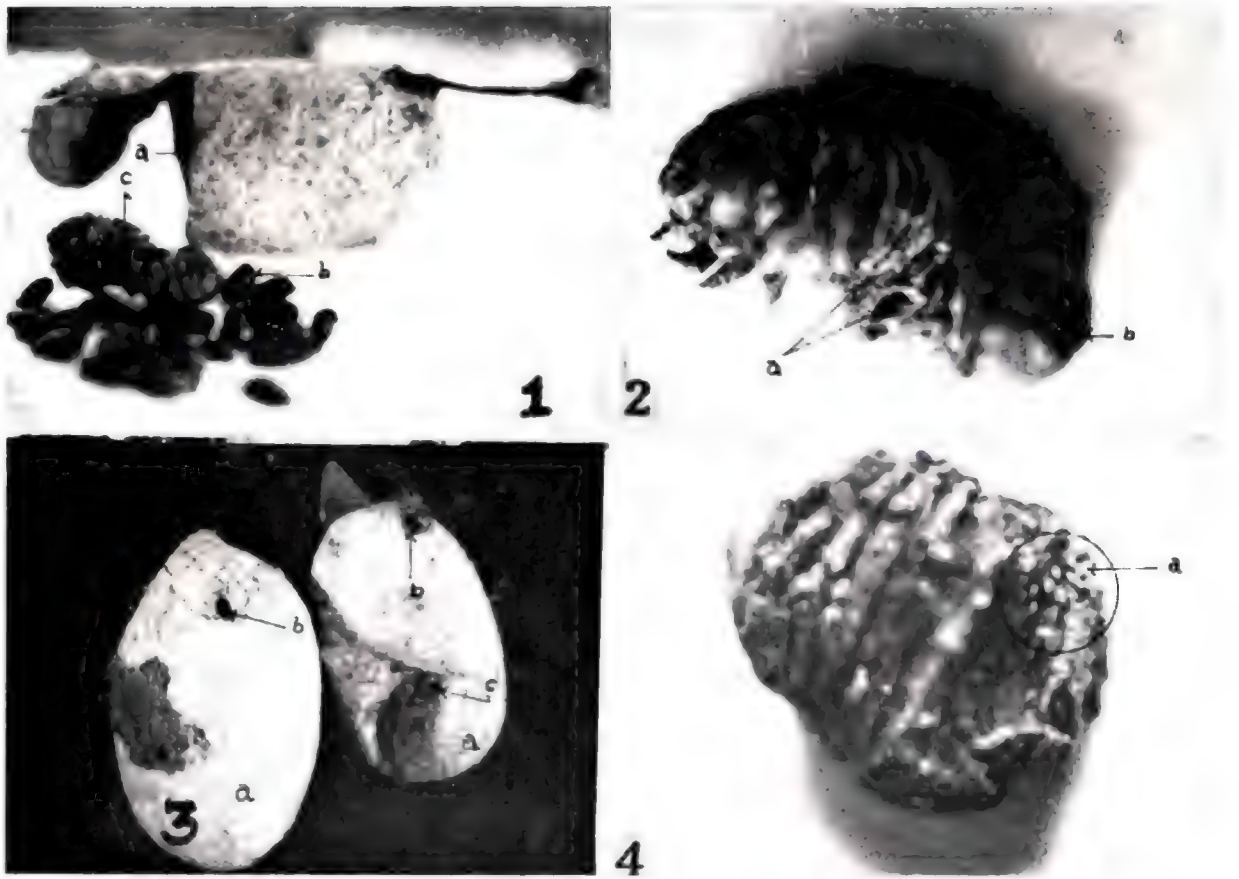

Fig. 1. Superparasitism by *B. zebina*. a. Cut open tasar cocoon; b. Uji puparia; c. Dead host larva.

Fig. 2. Dead tasar prepupa with emergence holes. a. Emergence holes on ventrolateral aspects; b. Dead host prepupa.

Fig. 3. Emergence holes on tasar cocoons. a. Uji pierced tasar cocoons; b. Emergence hole at peduncular end; c. Emergence hole at middle portion.

Fig. 4. Dead tasar larava showing the eggs a. deposited by the trapped adult uji fly.

TABLE 2. Emergence site of uji maggots on the pierced tasar cocoons.

Pierced cocoons (randomly grouped)	Emergence hole		
	Peduncle	Middle	Opposite
9	4	3	2
7	6	0	1
8	5	1	2
9	6	2	1
8	4	3	1
7	5	2	0
8	5	3	0
7	6	0	1
3	3	0	0
5	2	2	1
4	3	1	0
4	3	1	0
7	5	1	1
8	8	0	0
8	4	4	0
7	6	1	0
7	4	2	1
6	4	2	0
8	8	0	0
9	7	2	0
9	5	3	1
7	5	0	2
8	7	1	0
Total: 163	115 (70.55%)	14 (8.59%)	34 (20.86%)

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BIOLOGY AND CONTROL OF BLOSSOM MIDGE *CONTARINIA* SP. (DIPTERA : CECIDOMYIIDAE) ON *JASMINUM SAMBAC* IN TAMIL NADU

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The problem of occurrence of purple discolouration and premature drying of flower buds in *Jasminum sambac* Ait., was studied. The blossom midge *Contarinia* sp. (Diptera: Cecidomyiidae) was identified as the cause for the scourge. The life cycle of the midge was studied. Monocrotophos 0.1 % spray was found significantly effective in reducing the discolouration.

(*Key words*: *Jasminum sambac*, *purple discolouration*, *Contarinia* sp., *biology*, *chemical control*)

INTRODUCTION

Jasminum sambac Ait. cv. Gundumalli (Family: Oleaceae) is an important commercial flower crop of Tamil Nadu. The occurrence of purple discolouration and premature drying of flower buds has recently become a serious problem in the state, especially in the Rameswaram Island where more than fifty percent of flowers has been damaged during summer months. Though the blossom midge *Contarinia maculipennis* Feh had earlier been observed in the neighbouring Andhra Pradesh state as affecting the flower buds of *J. sambac* (THIRUMALA RAO *et al.*, 1954, 1955), it has not been earlier recorded in Tamil Nadu on *J. sambac*. Field and laboratory studies were therefore conducted at the Agricultural Research Station, Paramakudi during 1986–1987 to identify the midge, study its life cycle and determine effective chemical against the pest. This paper reports on the results of the above studies.

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MATERIALS AND METHODS

Half to three-fourths mature flower buds that were collected from the affected gardens in the Rameswaram Island and at Notchiyurani in the peninsula were kept on moist sand in insect cages. The emerging midges were collected at night, while the parasites were collected during the day. The specimens were sent to C.A.B. International Institute of Etnomology for identification.

In the laboratory, Petri dishes were filled with moist sand and planted with three-fourths mature flower buds. Adult midges were introduced into the cage that housed the dishes. Life history and symptoms of damage were studied. The experiments were conducted at 34 $\pm$ 2°C, 70 $\pm$ 10% RH.

In the field an experiment was conducted at Thangachimadam in Rameswaram Island. Seven treatments were included in a randomized block design with three replications. Each treatment had 10 bushes. All the flower buds were removed before treatment after counting the total number of flowers and discoloured flowers on each bush and

the percentage discolouration was arrived at. The chemicals were sprayed with a hand-operated knapsack sprayer upon the formation of tender buds. The percentage of purple discolouration was recorded twice, one and two weeks after the spray, by counting the discoloured buds to the total number of flower buds in each bush. The data were transformed into angular values before statistical analysis.

RESULTS

The cecidomyiid was identified as *Contarinia* sp. The hymenopteran parasites that inhabited the discoloured buds were *Microdontomerus* sp. (Torymidae), *Systasis* sp. (Pteromalidae), *Elasmus anticles* Walker (Elasmidae), *Tetrastichus* (S. str.) sp. and *Tetrastichus gala* Walker (Eulophidae), and *Bracon* sp. (Braconidae). The parasitization was observed to be 21.9 per cent in the field.

The cecidomyiid midges, both male and female, were 1.5 mm long with black head and yellowish brown body. The females were characterised by the presence of a distinct oviscapt. Either sex had moniliform antenna adorned with hairs in whorls. However, the antennal segments were long and cylindrical in female, short and spherical in male. At night the female laid elongate, cylindrical eggs by piercing the petals on inner 1–3 whorls of petals in groups ranging between 10 and 14. The eggs hatched in a day or two ($\bar{X} = 1.40 \pm 0.48 : n = 30$). The maggots were hyaline or dull white, fed on the tissues of corolla (inner 1–4 petals), anthers and stigma leaving the thalamus intact. Mature maggots that measured 2.5 mm became yellowish orange and fell down to the soil by throwing themselves away accomplished by bringing the two extremities of their body together and then straightening suddenly. The larval period lasted 4–5 days ($\bar{X} = 4.33 \pm 0.47 : n = 30$). Pupation occurred in the top layer of soil in a thin papery white case. The adults emerged in 7 or 8 days ($\bar{X} = 7.53 \pm 0.49 : n = 30$) and lived for 1–3 days ($\bar{X} = 2.03 \pm 0.65 : n = 30$). The whole life cycle occupied 13 to 18 days (Table 1). The petals showed signs of purple discolouration four or five days after oviposition by which time the maggots had reached the soil for pupation. The discoloured flowers finally got dried up three-fourths mature without opening.

The results of the field trial indicated that monocrotophos 0.1%, cypermethrin 0.012%, neem oil 2% plus Teepol 0.05 %, and fenvalerate 0.02 % were significantly superior to endosulfan 0.1 % and chlorpyriphos 0.05 % in reducing the percentage of purple discolouration caused by *Contarinia* sp. (Table 2). Monocrotophos was the most effective treatment as it was significantly superior to the rest of the chemicals even after two weeks after the spray.

DISCUSSION

This is the first record of *Contarinia* sp. occurring on *J. sambac* cv. Gundumalli in Tamil Nadu state causing puple discolouration of petals before drying. However, in Andhra Pradesh, THIRUMALA RAO *et al.* (1954) had earlier observed the cecidomyiid on *J. sambac* which was later identified as *Contarinia maculipennis* (THIRUMALA RAO *et al.*, 1955; MANI, 1973) probably on the idea that it should have been the same species which was originally described from Hawaii (JENSON, 1946; BARNER, 1948). The present species could not be confirmed as *C. maculipennis* until adequate taxonomic studies are made. Moreover, it is more likely that this species would probably be the one that occurred in Andhra Pradesh because DAVID (1958) had earlier recorded *C. maculipennis* on *Jasminum auriculatum* Vahl. at Coimbatore in Tamil Nadu where it caused only swelling at the base of the corolla.

TABLE 1. Duration in days of growth stages of *Contarinia* sp.

Life stage	Range	Mean ± SD
Egg[a]	1 – 2	1.40 ± 0.48
Larva[a]	4 – 5	4.33 ± 0.47
Pupa[a]	7 – 8	7.53 ± 0.49
Adult[a]	1 – 3	2.03 ± 0.65

[a]Based on 330 observations.

TABLE 2. Effect of insecticides and neem oil on *Contarinia* sp. (Percentage of discoloured flowers - Mean of 3 replications).

Treatments	Pre-treatment count	One week after spray	Two weeks after spray	Post-treatment
endosulfan 0.1%	50.49 (45.29) a	10.58 (18.98) a	64.19 (53.26) e	37.38 (36.12) b
monocrotophos 0.1%	46.68 (43.07) a	1.21 (6.19) a	10.19 (18.52) a	5.70 (12.36) a
chlorpyriphos 0.05%	45.33 (42.29) a	9.74 (18.11) a	52.14 (46.20) d	30.94 (32.16) b
cypermethrin 0.012%	51.58 (45.89) a	9.95 (18.33) a	24.71 (29.81) b	17.33 (24.07) ab
fenvalarate 0.02%	48.74 (44.27) a	11.90 (20.14) a	36.27 (37.05) c	24.09 (28.59) ab
neem oil 2% + teepol 0.05%	47.11 (43.33) a	9.82 (18.14) a	31.89 (34.38) c	20.86 (26.26) ab
untreated check	49.45 (44.66) a	60.45 (51.04) b	77.87 (61.97) f	69.16 (56.51) c

(Figures in parentheses are means of angular transformed values).

In a column, means followed by a common letter are not significantly different at 5 per cent level by DMRT.

The parasites recorded in the present study appear to be the first record on *Contarinia* sp. in *J. sambac* in India. However, MANI (1973) had noticed parasites belonging to Chalcidoidea and Cerphoidea (Platygasteridae) on *C. maculipennis* in *J. sambac* in South India.

It is evident from the present study that among the insecticides tested monocrotophos could be recommended against the midge in case the infestation is severe as it was found significantly superior to other insecticides and to neem oil even two weeks after the spray. The effect of synthetic pyre-

throids, namely, cypermethrin and fenvalerate, and of neem oil was also comparable to that of monocrotophos statistically. Cypermethrin and fenvalerate can therefore be used in alternate founds with monocrotophos to check the midge effectively and to avoid any secondary infestation of sucking pests like the red spider mite, *Tetranychus cinnabarinus* Boisdual. The effect of neem oil might be due to its repellent nature because it had been observed to reduce significantly the oviposition by brown planthopper *Nilaparvata lugens* (Stal) in rice (VELUSAMY *et al.*, 1987). Nevertheless, as it was observed in the present trial to have caused general chlorosis of the leaves two weeks after the treatment, it cannot be used on *J. sambac*.

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GENETIC VARIABILITY FOR QUANTITATIVE TRAITS IN SILKWORM *BOMBYX MORI* L.

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The phenotypic coefficient of variance value was slightly more compared to genotypic coefficient of variance for 18 quantitative traits tested in *Bombyx mori* L., indicating less environmental effect. The genetic advance ranged between 8.62 to 48.66 percent. It was more than 20 percent for larval weight, cocoon yield, cocoon weight, cocoon shell weight, cocoon filament length and weight, denier and silk waste. Further selection based on the above characters in the material will be highly effective for good improvement.

(*Key words*: *Bombyx mori*, genetic variability)

INTRODUCTION

Studies on genetic variability among silkworm breeds and hybrids are important as these would help to some extent to choose the method of breeding. At present, in Karnataka a large number of hybrid combinations with 'Pure Mysore' as female parent and improved bivoltine breeds as male component are being reared in various parts of State. Since 'C. Nichi' is having more of effective rate of rearing, shorter larval duration, moderate resistance to diseases and it is well acclimatized, this can be used as maternal component in place of 'Pure Mysore' in hybrid combinations with bivoltine paternal parents. Studies concerning the variability of silkworm breeds and hybrids, involving 'C. Nichi' as one of the parental breeds, are not available. Hence, the present study is an attempt to know the nature and extent of genetic variability for eighteen quantitative traits.

MATERIALS AND METHODS

A multivoltine breed 'C. Nichi' and five bivoltine breeds namely 'Saniish–18' (SH), 'J_{122}' (J), 'Kalimpong–A' (KA), 'NB_{18}' and 'NB_7' were utilized as parents. Five multi × bi and eight bi × bi single cross hybrids and eight each of three-way direct and reciprocal crosses were prepared as shown below.

Single crosses

Multi × bi	*Bi × bi*
CN × SH	SH × J
CN × J	J × SH
CN × KA	SH × 'NB_{18}'
CN × 'NB_{18}'	'NB_{18}' × SH
CN × 'NB_7'	J × 'NB_{18}'
	'NB_{18}' × J
	KA × 'NB_7'
	'NB_7' × KA

Three-way crosses:

Direct crosses	*Reciprocal crosses*
CN × (SH × J)	(SH × J) × CN
CN × (J × SH)	(J × SH) × CN
CN × (SH × 'NB_{18}')	(SH × 'NB_{18}') × CN
CN × ('NB_{18}' × SH)	('NB_{18}' × SH) × CN
CN × (J × 'NB_{18}')	(J × 'NB_{18}') × CN
CN × ('NB_{18}' × J)	('NB_{18}' × J) × CN
CN × (KA × 'NB_7')	(KA × 'NB_7') × CN
CN × ('NB'$_7$ × KA)	('NB_7' × KA) × CN

All parents and hybrids were reared twice during January to April, 1987. Three replications were maintained for each. A single disease free laying formed a replication. The standard method for young and late age silkworm rearing was practised as recommended by KRISHNASWAMI (1978; 1979).

Data were collected on 18 quantitative traits from January–February and March–April rearings and pooled together and analysed. The genetic parameters were computed by employing the following standard procedure (SINGH & CHAUDHARY, 1977).

1. Phenotypic variance:

$$\frac{\text{Treatment of M.S.S.}}{\text{No. of replications}}$$

2. Phenotypic coefficient of variance:

$$\frac{\sqrt{\text{Phenotypic variance}}}{\text{Overall mean}} \times 100$$

3. Genotypic variance:

$$\frac{\text{Treatment M.S.S.} - \text{Error M.S.S.}}{\text{No. of replications}}$$

4. Genotypic coefficient of variance:

$$\frac{\sqrt{\text{Genotypic variance}}}{\text{Overall mean}} \times 100$$

5. Heritability in breed sense:

$$\frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times 100$$

6. Genetic Advance:

$$\frac{\text{Heritability} \times \sqrt{\text{Phenotypic variance}} * k}{\text{Overall mean}}$$

(k is constant = 2.06)

RESULTS AND DISCUSSION

The data on the mean values were used for finding out the values of phenotypic and genotypic co-efficient of variance. heritability in broad sense and genetic advance for differ ent quantitative traits and they are presented in Table 1 and are discussed as follows:

Phenotypic and genotypic variance:

The maximum phenotypic variance was observed in cocoon filament length (29727.29) followed by larval duration, fecundity and pupal duration and it was minimum in cocoon filament weight (0.0037). Cocoon weight and cocoon shell weight yielded phenotypic variance of 3.73 and 0.3329. respectively.

The genotypic variance values were nearly less as compared to phenotypic variance values. However, the trend was same as that of phenotypic variance. The genotypic variance exhibited a range of 0.0036 (cocoon filament weight) to 28461.73 (cocoon filament length). Next in order were fecundity (2930.14), larval duration (2108.59) and pupal duration (405.40).

Phenotypic and genotypic coefficient of variance:

The highest phenotypic co-efficient of variance was recorded for cocoon filament weight (24.54%) and next in order were cocoon shell-weight. cocoon filament length, silk waste, denier, cocoon yield for 10,000 worms brushed. larval weight just before

TABLE 1. Extent of genetic variability for different quantitative traits of silkworm.

Sl no.	Characters	Phenotypic variance	Phenotypic coefficient of variance	Genotypic variance	Genotypic co-efficient of variance	Heritability in broad sense (%)	Genetic advance (%)
1.	Larval weight before settling for third moult	0.0365	12.16	0.0362	12.11	99.06	24.85
2.	Progression to fourth instar	13.18	5.33	11.74	5.02	89.09	9 77
3.	Maximum larval weight	22.31	12.09	22.11	12.05	99.12	24.23
4.	Larval duration	3337.12	9.82	2108.59	7.80	63.19	12.78
5.	Effective rate of rearing	23.72	6.58	23.14	6.50	97.57	13.23
6.	Cocoon yield per 1000 worms brushed	4.41	12.40	4.35	12.31	98.53	25.17
7.	Cocoon weight	3.73	10.88	3.61	10.70	96.72	21.67
8.	Pupal weight	1.99	9.75	1.90	9.51	95.02	19.09
9.	Cocoon shell weight	0.3329	17.99	0.3180	17.58	95.54	33.38
10.	Cocoon shell ratio	1.67	5.16	1.35	4.65	81.05	8.62
11.	Pupal duration	437.59	7.29	405.40	7.00	92.64	13.87
12.	Moth emergence	12.20	4.55	11.80	4.48	96.75	9.04
13.	Fecundity	3168.22	10.27	2930.14	9.88	92.48	19.57
14.	Hatching percentage	8.86	4.04	6.17	3.37	69.69	5.80
15.	Cocoon filament length	29727.29	17.82	27461.72	17.13	92.34	33.91
16.	Cocoon filament weight	0.0037	24.54	0.0036	24.08	96.27	48.66
17.	Denier	0.0859	12.75	0.0708	11.57	82.40	21.63
18.	Silk waste	11.02	13.90	8.27	12.04	75.03	21.48

settling for third moult and maximum larval weight recording 17.99, 17.82, 13.90, 12.75, 12.40, 12.16 and 12.09, respectively. The lowest was registered by hatching percentage (4.047%).

The study of only phenotypic co-efficient of variability would not help in improving quantitatively inherited traits. The success of selection is governed by the degree to which the desired trait is transmitted to the next generation. Therefore, it is necessary to assess the extent of genetic co-efficient of variability. It was observed that in all the crosses the genotypic co-efficient of variability was less than the phenotypic co-efficient of variability as is perhaps to be expected. The highest genotypic co-efficient of variance was recorded for cocoon filament weight (24.08%) followed by cocoon shell weight (17.58%), cocoon filament length (17.14%) and cocoon yield for 10,000 worms brushed (12.31%). The lowest was yielded by hatching percentage (3.37%) (Table 1).

The difference between genotypic and phenotypic co-efficient of variance was less. Hence, it indicates less environmental effect and greater scope for selection towards increased expression of the above traits from the point of genotypic variability. SEN *et al.* (1976) reported the genotypic coefficient of variance of 78.70, 6.31 and 9.48 percent for fecundity, cocoon weight and cocoon shell weight, respectively in tasar silkworm. *Antheraea mylitta* D. In the present studies the corresponding values were respectively 9.88, 10.70 and 17.58 percent. The deviation may have to be attributable to the species involved.

Heritability:

Heritability in broad sense is the ratio of genetic to the total variability existing in the material. The characters which showed high heritability can be used to explore the possibility of employing further selection on the material for the improvement. The heritability in broad sense of above 99 percent was encountered for maximum larval weight (99.12%) and larval weight just before settling for third moult (99.06%). The heritability over 90 percent was registered for cocoon yield for 10,000 worms brushed (98.53%), effective rate of rearing (97.57%), moth emergence (96.75%), cocoon weight (96.72%), cocoon filament weight (96.27%), cocoon shell weight (95.54 %), pupal weight (95.02%), pupal duration (92.64%), fecundity (92.48%) and cocoon filament length (92.38%). Only four characters showed less than 90 percent heritability in broad sense. SEN *et al.* (1976) observed in *A. mylitta* the heritability of 79.20, 87.94 and 85.89 percent for fecundity, cocoon weight and cocoon shell weight, respectively. As in the current studies, GAMO & HIRABAYASHI (1983) reported the broad sense heritability values of 0.849, 0.918 and 0.968 for cocoon weight, cocoon shell weight and cocoon filament length, respectively in *B. mori.*

Genetic advance:

Heritability estimate in broad sense by itself provides no indication of the amount of genetic gain that would result from selecting the best individuals, but heritability along with estimates of genetic gain is usually more useful (JOHNSON *et al.*, 1955).

It is particularly worthy to note the extent of genetic advance in the characters cocoon filament weight (48.66%), cocoon shell weight (35.38%), cocoon filament length (33.95%), cocoon yield for 10,000 worms brushed (25.17%), larval weight just before settling for third moult (24.85%), maximum larval weight (24.23%), cocoon weight (21.67%), denier (21.63%) and silk waste (21.48%). Therefore, further selection based on the above characters in the material will be highly effective for good improvement. The genetic advance of 68.91 percent for fecundity, 1.57 percent for cocoon weight and 0.35 percent for cocoon shell weight, was observed in *A. mylitta.* (SEN *et al.*, 1976).

The characters larval, pupal, cocoon and cocoon weights, filament length and weight, cocoon shell weight, cocoon yield, denier and silkwaste recorded high heritability as well as high genetic advance indicating possible operation of additive gene action and simple phenotypic selection can be employed to improve them. The traits moth emergence, effective rate of rearing, larval and pupal duration, progression to fourth instar, cocoon shell ratio and hatching showed high heritability but low genetic advance implying that the operation of non-additive gene action may be predominant and for these traits hybridization and recurrent selection will yield good response.

In general, the maximum extent of genetic variability has been observed for larval weights, effective rate of rearing, cocoon yield, cocoon shell weight, cocoon filament length and weight, denier and silk waste. Hence, these characters can be considered for further selection process to generate elite material.

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HETEROSIS FOR PUPAL AND RELATED TRAITS IN SINGLE AND DOUBLE CROSS HYBRIDS OF BIVOLTINE SILKWORM *BOMBYX MORI* L.

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Heterosis/improvement for pupal and related traits in four single and eight double cross hybrids of silkworm (*Bombyx mori*) was studied. Among four bivoltine single cross hybrids, 'J_{122}'×'NB_{18}' and KA ×'NB_7' showed significant heterobeltiosis for two traits each. Out of eight double cross hybrids ('J_{122}' ×'NB_{18}') ('NB_7'×KA) gave significant relative improvement for two traits.

(*Key words*: *Bombyx mori*, heterosis, pupal traits)

INTRODUCTION

Hybrids in general are superior to parental breeds in growth, vigour and other economic characters. In order to boost up the silk production of International standards. India has been giving more importance for bivoltine silk production. Now-a-days the demand for hybrids has been increasing. The demand for silkworm eggs during VIIth plan is 30 crore DFI's, but the present production of the same amounts to only 10 crores (NARASIMHANNA, 1985). With a view to meet this expected requirement the moths of already available bivoltine single cross hybrids can be effectively utilized for producing double cross hybrid seed which can be distributed amongst farmers for commercial cocoon production thereby cost of seed production can be cut down to a considerable extent. Also at times of scarcity of single cross hybrid seed, double cross hybrid seed can be supplemented along with single cross hybrid seeds. The other additional advantages with double crosss hybrid silkworms are that they can be reared easily and their yields are on par or even better than single cross hybrids. Considering all the above points. the extent of heterosis is bivoltine silkworm in single cross hybrids and improvement in double cross hybrids were studied.

MATERIALS AND METHODS

Four single cross hybrids and eight double cross hybrids of four bivoltine races viz., 'J_{122}', 'NB_{18}', 'NB_7' and 'Kalimpong–A' (KA) were reared in three different rearings viz., September – October, November–December and January–February, 1986–1987 at the Department of Sericulture, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka. Early and late instar worms were reared according to standard rearing procedures (KRISHNASWAMI, 1978; 1979) using 'Kanva–2' variety of mulberry leaves. Observations were recorded on pupal weight, pupal duration, pupal mortality, fecundity and hatching percentage. The data of three rearings were pooled and by using mean values the extent of heterosis/improvement was calculated by the methods already available (TURNER, 1953; HAYES *et al.*, 1955). The significance of heterosis/improvement was marked by using the critical difference values.

RESULTS AND DISCUSSION

Pupal weight:

Heterosis for pupal weight over corresponding better parent was significant only in KA × 'NB_7' (15.30%). The hybrids 'J_{122}' × 'NB_{18}' and 'NB_{18}' × 'J_{212}' gave significant relative heterosis. The double cross hybrid ('NB_7' × KA) ('NB_{18}' × 'J_{122}') gave improvement over corresponding mid-foundation parental value. None of the double cross hybrids gave significant improvement over corresponding better parent. A gain of 14.82 percent over mid-parental value for pupal weight in F_1 cross between Daba and Bogai of tasar silkworm (*Antheraea mylitta*) was reported (PANIGRAHI, 1974). GAMO & HIRABAYASHI (1983) opined that the pupal weight could be improved by heterosis in F_1 hybids.

Pupal duration:

None of the hybrids yielded significant negative desirable heterosis over corresponding better parent. 'NB_7' × KA among single cross hybrids and ('J_{122}' × 'NB_{18}') (KA × 'NB_7') among double cross hybrids yielded significant negative heterosis/improvement over corresponding mid-parental value.

Pupal mortality:

Desirable negative significant improvement over corresponding better parent was exhibited by ('J_{122}' × 'NB_{18}') ('NB_7' × KA) (–27.86%). None of the hybrids exhibited negative significant heterobeltiosis. Documented literature concerning this trait is not available.

Fecundity:

The single cross hybrids 'J_{122}' × 'NB_{18}' (17.35%), 'NB_{18}' × 'J_{122}' (21.04%) and KA × 'NB_7' (15.76%) registered significant heterosis. Among double cross hybrids, ('J_{122}' × 'NB_{18}') ('NB_7' × KA) (13.00%) and ('NB'_{18} × 'J_{122}') ('NB_7' × KA) (16.03%) resulted in significant improvement over corresponding foundation parents. A high expression of heterosis was observed for fecundity in *A. mylitta* double cross hybrids, compared to single and three-way cross hybrids (BARDAIYAR *et al.*, 1976). Significant improvement was noticed in double cross hybrids. BENCHAMIN & KRISHNASWAMI (1981) also reported that the double cross hybrids were most effective for application of the byhrid advantage in egg production for commercial exploitation. The heterosis over mid-parent value for fecundity showed no superiority in *A. mylitta* (NARASIMHANNA *et al.*, 1981).

Hatching percentage:

Heterosis/improvement for hatching percentage was not significant in positive direction among the double cross hybrids. The single cross hybrid 'J_{122}' × 'NB_{18}' gave significant heterobeltiosis of 6.22%. 'NB_7' × KA yielded significant relative heterosis of 5.65%. TAYADE (1987) observed significant positive heterosis either over mid parent or better parent for hatching percentage. The deviation may be attributable to the genetic distance of the breeds employed in the studies.

According to FALCONER (1985), heterosis is a function of dominance effect and genetic distance between the parents. It has been shown that $H = \leq dy^2$ where 'd' is the dominance effect and 'y' is the genetic distance between the two. By the above formula it is quite obvious that when 'd' and 'y' ($0 \leq y \leq 1$) are maximum, 'H' is maximum. Higher 'd' is observed with higher heterozygocity. When two completely homozygous parents (inbreds) are crossed, maximum heterozygocity can be achieved. In view

TABLE 1. Heterosis improvement for pupal and related characters in bivoltine silkworm single and double cross hybrids.

Sl. no.	Hybrids	Pupal weight		Pupal duration		Pupal mortality		Fecundity		Hatching percentage	
		Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent	Mid parent	Better parent
I.	*Heterosis*										
1.	'J_{122}' x 'NB_{18}'	16.54**	8.49	–5.46	0.79	–4.19	6.10	18.97**	17.35*	6.96**	6.22*
2.	'NB_{18}' x 'J_{122}'	14.19**	6.33	–2.48	3.96	–17.78	–8.98	22.72**	21.04**	3.32	2.61
3.	'NB_7' x KA	6.95	4.83	–7.59*	–3.27	1.91	8.77	2.52	–0.13	5.65*	2.27
4.	KA x 'NB_7'	17.63**	15.30**	–0.78	3.85	–11.41	–5.43	18.83**	15.76*	0.29	–1.47
II.	*Improvement*										
1.	('J_{122}' x 'NB_{18}') ('NB_7' x KA)	1.13	1.02	–3.40	–3.08	27.86*	17.58	13.00*	8.87	3.77	9.13
2.	('J_{122}' x 'NB_{18}') (KA x 'NB_7')	2.10	–2.62	–6.24*	1.57	–16.83	–11.99	3.93	–0.05	–2.32	–10.59*
3.	('NB_{18}' x 'J_{122}') 'NB_7 x KA)	0.002	–1.09	2.60	5.34	8.63	35.63	16.03**	10.15	–2.74	–5.47
4.	('NB_{18}' x 'J_{122}') (KA x 'NB_7')	4.87	–0.93	1.73	8.39	11.55	28.35	–4.13	–6.03	–2.10	–8.40
5.	('NB_7' x KA) ('J_{122}' x 'NB_{18}')	4.85	4.80	0.25	4.59	–6.28	7.06	5.15	1.31	–4.36*	–8.94*
6.	('NB_7' x KA) ('NB_{18}' x 'J_{122}')	8.81*	7.62	2.60	5.34	–18.43	1.82	6.84	1.43	–3.11	–8.31
7.	(KA x 'NB_7') ('J_{122}' x 'NB_{18}')	1.89	–2.79	–5.27	2.62	–24.97	–20.62	9.05	5.27	–3.13	–7.49*
8.	(KA x 'NB_7') ('NB_{18}' x 'J_{122}')	0.11	–5.41	0.53	7.12	–12.36	0.86	4.32	2.23	–0.99	–8.26
	S Em ±	0.66	0.76	8.38	9.67	1.59	1.85	30.33	35.01	1.57	1.82
	C D at 5%	1.35	1.56	17.10	19.73	3.26	3.77	61.93	71.44	3.21	3.70
	C D at 1%	1.81	2.09	23.04	26.59	4.37	5.09	83.41	96.28	4.32	5.01

* Significant.

** Highly significant.

of this, the single cross hybrids showed more heterosis and low degree of heterozygocity caused less improvement in double cross hybrids.

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IMPACT OF NATIVE PARASITOIDS ON RICE LEAF FOLDER *CNAPHALOCROCIS MEDINALIS* GUENEE (PYRALIDAE : LEPIDOPTERA) IN SOUTHERN SRI LANKA

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The native parasitoids *Macrocentrus* spp., *Elasmus brevicornis* Gahan and *Argyrophylax* spp. were the primary parasitoids attacking larvae of rice leaf folder *Cnaphalocrocis medinalis* Guenee in unsprayed rice field in Southern Sri Lanka from 1986–1987 cultivation season. Parasitoids destroyed 61.82 percent, each of the first three instars and *E. brevicornis* emerged from 64% of the parasitized larvae. *Macrocentrus* spp. and *E. brevicornis* did not emerge from larvae having head capsule widths greater than 1.7mm. A comparison of parasitism pattern between *Macrocentrus* spp. and *E. brevicornis* revealed that these patterns were almost mirror images of each other. Larvae not producing parasitoids were classified as nonparasitised and they became adult moths, died due to unknown reasons or became diseased and died.

(*Key words*: *Cnaphalocrocis medinalis*, *Macrocentrus* spp., *Elasmus brevicornis*, parasitoids, rice)

INTRODUCTION

The rice leaf folder *Cnaphalocrocis medinalis* Guenee. (Lepidoptera : Pyralidae) is distributed throughout south and southeast Asia. China, Japan and the South Pacific Islands (GRIST & LEVER, 1969). The larvae damage the leaves by spinning a rice leaf longitudinally into a roll, by stitching together opposite rims of leaf and to feed inside this roll, leaving the epidermis on the outside of the roll intact (FRAENKEL & FALLIL, 1981). Leaf folder infestations were extremely severe in North Vietnam in 1981 (BAUTISTA et al., 1984) and outbreaks have been reported in North Bengal, India (CHATTERJEE, 1979) and Southwestern Japan (HIRAO, 1981). This pest appears to be gaining importance with the spread of high yielding rice varieties and accompanying changes in cultural practices (BAUTISTA et al., 1984). Improperly applied pesticides and high fertilizer rates cause increases in leaf folder populations (DHALIWAL et al., 1979).

The research related to biological control in rice is confined to studies of seasonal and relative abundance on taxonomic surveys of natural enemies (SHEPARD & ROMBACH, 1984). Although successful introduction of biological control agents for rice insect control is limited, a substantial amount of information is available which shows the relative importance of indigenous natural enemies which attack rice pests. There are rich communities of biological control agents which attack rice insect pests in the abscence of chemical insecticide treatments and the efficacy of these natural enemies should be given a thorough evaluation. Therefore the major effort was to determine the impact of native parasitoids on rice leaf folder populations in rice not sprayed with insecticides.

These series of field experiments were conducted at University Farm, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya between 1986–1987 Yala (April–July) and Maha (Sep.–Jan.) seasons.

MATERIALS AND METHODS

At Mapalana, University Farm, five adjacent study plots were set up in the centre of a 10 ha field previously used to produce rice. Each plot encompassed 13.25 × 16.5 m and

was rainfed using Yala and Maha monsoonal rains. Plot preparation consisted of uniform distribution 16 kg of rice variety 'BG 276–6B' and disking it to a depth of approximately 2 cm. No fertilization, insecticidal application or additional cultivation occurred during the experimental period. Study plots were planted at 1 week intervals and weekly samples were collected from 1986 and 1987 Yala and Maha seasons, from all plots having rice leaf folder infestation. Sampling occurred at four equally spaced locations along a transect passing through the centre of each plot and running parallel to the plot's long axis. A single sample consisted of harvesting all of the rice plants in a 6 cm^2 area. These were placed in plastic bags and transported to the Laboratory, where each plant was completely taken apart and examined for rice leaf folder larvae. A dissecting microscope was used for species identification and head capsule widths (HCW) were taken to determine the age distribution of the larval population. Each leaf folder larva was then placed in a 50 ml plastic cup containing cut rice leaves for the larva to complete its development. The cups were checked daily and the fate of each larva was recorded. The above procedure was continued for four seasons (1986 and 1987 Yala and Maha).

RESULTS AND DISCUSSION

In order of abundance, *Macrocentrus* spp., *Elasmus brevicornis*, *Argyrophylax* spp. were the three principal parasitoids collected from the study plots (Fig. 1). *Chelonus* spp.,

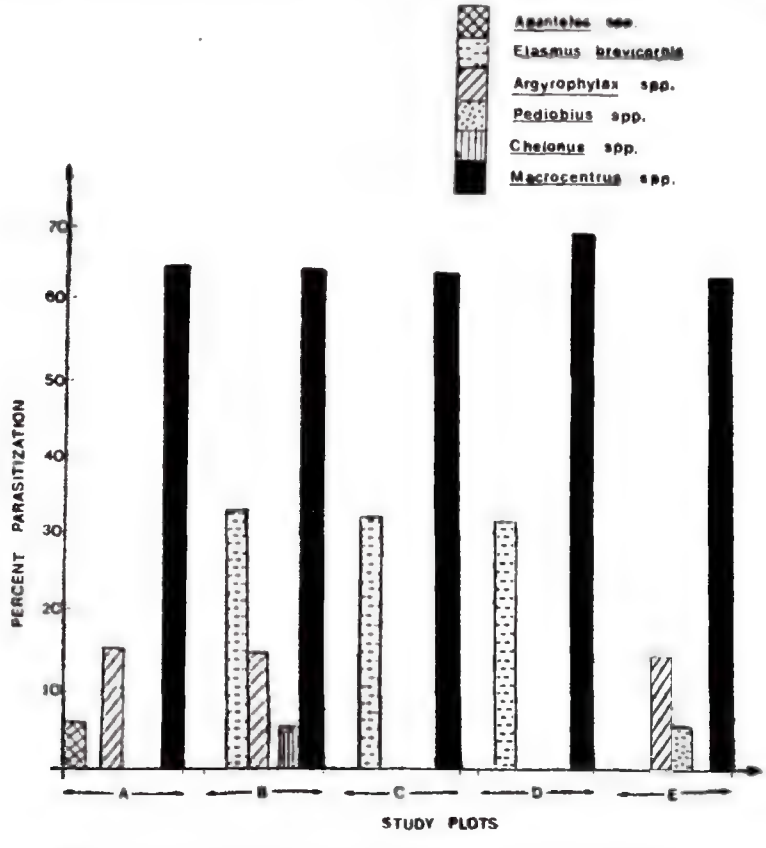

Fig. 1. Percent parasitism of rice leaf-folder larvae by six parasitoid species in 5 study plots at Mapalana.

Apanteles spp. and *Pediobius* spp. and a small group of unidentified ichnuemonids accounted for only a small portion of rice leaf folder larval mortality. Rice leaf folder collections made from 1986 Yala and 1986 Maha produced parasitism levels 33.3% and 64% for *E. brevicornis* and *Macrocentrus* spp. (unpublished data, Rajapakse). Collections of leaf folder larvae at International Rice Research Institute, Philippines fields revealed that parasitoids killed over 30% of the larvae (SHEPARD & ROMBACH, 1984). The four major genera of larval parasitoids reported from IRRI, Philippines were *Goniozus* spp., *Cardiochiles* spp., *Copidosoma* spp. and *Cotesia* spp. With the exception of *Goniozus* spp. these parasitoids were not collected from rice in Sri Lanka. In the collections from Southern Sri Lanka *Goniozus* spp. was also the principal parasitoid and *Macrocentrus* spp. and *E. brevicornis* ranked second and third in abundance, from surrounding rice fields (Table 1).

The mean head capsule width (HCW) determined at the time of collections of host larvae parasitized by the principal parasitoids ranged from 0.4 to 0.6 mm. This narrow range and the small HCW indicated that the smaller larvae were primarily parasitized by the dominant parasitoid species.

Planting the study plots at 1 week interval permitted a temporal analysis of parasitism (Fig. 1). *Macrocentrus* spp. was the most frequently recovered parasitoid in all five of the study plots and exhibited the most stable parasitism rate. *Apanteles* spp. was the least abundant of the three principal parasitoids species in plot A. However in plots B, C, D and E, there was no parasitism by *Apanteles* spp., *Elasmus brevicornis* achieved its highest rate of parasitism in plot B and then remained relatively constant in plot C and D. However *E. brevicronis* then displayed an abrupt reduction in plot E and was not present in plot A.

TABLE 1. Parasitoids recovered from *Cnaphalocrocis medinalis* at Mapalana during 1986-1987.

Parasitoid	No. of rice leaf-folder larvae parasitized[a]	Percent[b]	Mean HCW[c]
Macrocentrus spp.	348	31.51	0.56
Elasmus brevicornis	120	14.51	0.80
Argyrophylax spp.	36	8.32	0.57
Goniozus spp.	348	32.00	0.51
Bracon spp.	84	4.00	0.56
Pediobius spp.	12	5.55	0.62
Chelonus spp.	72	1.05	0.56
Phanerotoma spp.	60	1.30	0.63
Unidentified	23	1.76	0.83
Total	1103	100.00	

a – Total rice leaf-folder larvae that produced only the said parasitoid. Each leaf-folder larva produced only one parasitoid.

b – Percentage calculated from total number of parasitized leaf-folder larvae.

c – A dissecting microscope was used to measure head capsule widths in mm.

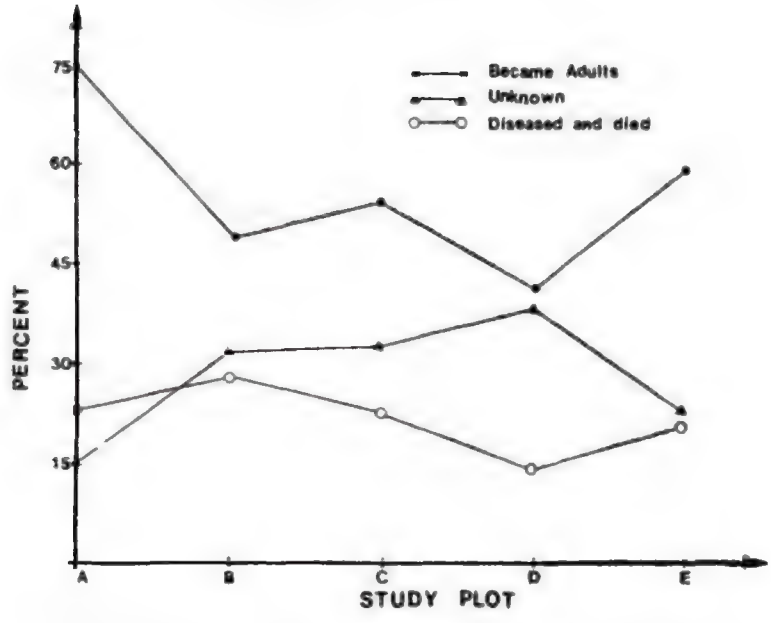

Fig. 2. Percent non parasitized rice leaf-folder larvae that emerged as adults, died from unknown causes or died after becoming diseased.

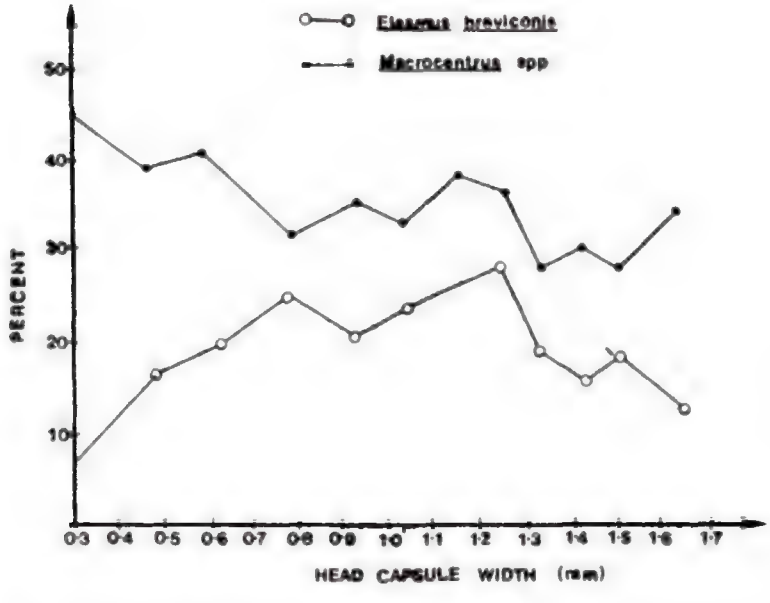

Fig. 3. Percent parasitism for 2 principal parasitoids by head capsule widths recovered from rice leaf folder larvae.

Macrocentrus spp. parasitized the greatest proportion of rice leaf folder larvae at each HCW but was most prevalent in larvae each having HCW of 0.3 mm (Fig. 3). This result was not unexpected because *Macrocentrus* spp. is an efficient larval parasitoid: larvae with the smallest HCW have the lowest probability of having encountered another parasitoid. The percent parasitism by *Macrocentrus* spp. increased substantially for larvae having HCW from 1.3 to 1.7 mm. This increase was probably a function of the larger larvae becoming less suitable or available for parasitism by the other parasitoid species. *Elasmus brevicornis* had its greatest impact on larvae having HCW between 0.8 and 1.3 mm. A substantial decrease in parasitism occurred in *E. brevicornis* for hosts having HCW greater than 1.3 mm. This reduction may reflect a lower threshold for host acceptance and suitability due to increased larval size and age. *Macrocentrus* spp. and *E. brevicornis* were not recovered from larvae having HCW greater than 1.7 mm. Non parasitized rice leaf folder larvae can achieve HCW of 3.0 mm. A comparison of parasitism patterns between *Macrocentrus* spp. and *E. brevicornis* reveals that these patterns were almost mirror images of each other (Fig. 3). This is interesting because the parasitism values were calculated from all larvae (parasitized and non parasitized) having the same HCW and therefore these corresponding increase-decrease and decrease-increase patterns between these two parasitoids were not a function of the method used to calculate these percentages. This mirror image pattern of parasitism may be indicative of interspecific competition between *Macrocentrus* spp. and *E. brevicornis*.

Based on laboratory experiments and in combination with the frequency distribution of HCW of all larvae collected during the 2 year investigation period, a head capsule range was established for each rice leaf folder instar (Table 2). The percent parasitism in the first three instars remained constant and then decreased substantially for the 4th and 5th instars. The largest numerical decrease in larval abundance occurred between 1st and 2nd instars, whereas the greatest percent decrease occurred between the 4th and 5th instars. The higher parasitism rates in the first three instars would be expected since the principal parasitoids could destroy these hosts, before the fourth instar. However the degree of consistency in the parasitism rates present within the first three instars was not expected.

TABLE 2. The percentage parasitism for all rice leaf-folder larvae collected during experimental period.

Head capsule range (mm)[a]	Estimated instars	% Parasitisation	No. of leaf-folder larvae	% decrease between instars
0.3 - 0.4	1	61.05	348	
				61.05
0.5 - 0.6	2	64.00	120	
				14.73
0.7 - 0.9	3	60.41	84	
				8.8
1.0 - 1.6	4	35.7	72	
				6.3
1.7 - 2.0	5	23.1	60	

a - HCW range was determined for each instar.

Those rice leaf folder larvae that did not produce parasitoids were classified into 3 categories (1) larvae that successfully pupated and became adults (2) larvae died due to unknown reasons (3) larvae that died due to diseases. The proportion of nonparasitized larvae from each study plot that became adults was always greater than those that died from unknown causes or diseased (Fig. 2). With the possible exception of plot A and E, larvae that died due to unknown reasons displayed a similar pattern between study plots throughout the entire collection period. The reasons for the fluctuation observed in these three categories of nonparasitized larvae are not presently understood but may be related to climatic conditions since succeeding plots were separated in time by a 1 week long interval.

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STEROL CONTENTS OF THE SILKWORM (*BOMBYX MORI* L.) EGGS

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Cholesterol is the major sterol in silkworm eggs. The eggs of bivoltine ('NB_4D_2') race contain more sterols, and greater percentage of them are esterified, than those of the multivoltine ('Mysore pure') race. Diapause increases the sterol levels, whereas the acid-treatment of eggs reduces them.

(*Key words*: sterols in silkworm eggs, cholesterol, diapause, acid-treatment of eggs)

INTRODUCTION

The cholesterol content in the tissues of many insects is known (KIRCHER, 1982). Although several sterols have been detected in insect tissues, it is only the cholesterol that predominates quantitatively (KRITCHEVSKY, 1958; KIRCHER, 1982). It is known that the cholesterol content of both vertebrate and invertebrate tissues is partly dietary-dependent (KRITCHEVSKY, 1958; MONROE, 1960). Mulberry silkworm contains an appreciable amount of cholesterol in its tissues and body fluids, but surprisingly its diet lacks cholesterol (MORISAKI *et al.*, 1983). It is known that the silkworm tissues can convert the mulberry leaf-sterols after their assimilation, to cholesterol (MORISAKI *et al.*, 1983). Reports on the cholesterol content of insect eggs are, however, scanty. DUTKY *et al.* (1963) reported on the steryl ester content of housefly. The esters are probably the storage forms of sterols and are hydrolyzed during embryogenesis (CASIDA *et al.*, 1957; MONROE *et al.*, 1967). The sterols are not excreted in *Bombyx mori* at any stage of the life cycle but are stored in eggs (ICHIMASA, 1976). The objective of the present study is to analyze the sterol composition of the eggs of a multivoltine silkworm and to compare them with those of a bivoltine race.

MATERIALS AND METHODS

The eggs of Mysore Pure (multivoltine) and 'NB_4D_2' (bivoltine) race silkworm (*Bombyx mori* L.) were obtained from Government Grainages.

Two grams of eggs or mulberry leaf were homogenized in acetone-alcohol (1:1 by volume) using a tissue grinder to extract 3 β-OH sterols. The solution was separated by centrifugation at 600 *g*. The supernatant solution was saponified according to WHEELER *et al.* (1987), and the sterols were obtained as digitonides (RHEE *et al.*, 1982). The digitonide was separated by centrifugation at 1500 *g*, purified by repeated washings of acetone-alcohol, and centrifuged again. The separated digitonide was subjected to colorimetric assay using cholesterol (Sigma Co) as standard (RHEE *et al.*, 1982).

The analysis of sterol residue was done by analytical gas chromatography according to AOAC (1976) method on 30% SP-2250 on 'Supelcoport' mesh 100/120 using a flame ionization detector (Model 3920,

Perkin-Elmer Corp. Norwalk, Connecticut). Equilibrated columns of 2 mm ID and 2.44 m length were used at column temperature 270°C, detector cell 300°C and flash heat 300°C. Nitrogen was the carrier gas at a flow rate of 38 ml/min.

RESULTS

The data presented in the Table 1 show four important observations. They are: (1) the bivoltine race eggs contain three times more sterols than the eggs of the multivoltine race; (2) the eggs of the bivoltine race contain nearly two thirds of its total sterols as esters; (3) the diapausing eggs of the bivoltine race contain higher sterol levels than the freshly laid, post-diapausing or acid-treated eggs of the same race, and (4) the acid treatment reduced 35.5% of the sterol level present in the diapausing eggs.

Both the races differ in their egg sterol composition (Table 2). Cholesterol is singularly absent in the mulberry leaf. The eggs of the multivoltine ('Mysore Pure') race contain greater percentage of its total sterols as cholesterol than those of the (bivoltine) 'NB_4D_2' race. Evidently, the eggs contain the cholesterol as predominant sterol. In the leaf, β-sitosterol is the predominant sterol, while stigmasterol is the next constituent. Silkworm eggs contain five sterols viz., cholesterol, β-sitosterol, stigmasterol, campesterol, and brassicasterol. The brassicasterol occurs in traces in the eggs of the 'Mysore Pure' race.

DISCUSSION

The results demonstrate that the cholesterol in the eggs of the silkwarm does not have a dietary origin. The worm is capable of converting β-sitosterol, stigmasterol,

TABLE 1. Sterol contents[a] of mulberry leaf and silk worm (*Bombyx mori* L.) eggs.

Material	Average per cent hatching	Per-cent dry wt.	No. per g wet wt.	mg sterols per g wet wt. of eggs[b]		
				Free	Esterified	Total
I. Mulberry leaf ('M-5' variety)	—	—	—	0.13 ± 0.08	0.012 ± 0.01	0.14 ± 0.07[c]
II. Silkworm eggs						
a) 'Mysore pure'	96.26	21.65	2165	0.79 ± 0.13	0.011 ± 0.009	0.82 ± 0.06
b) 'NB_4D_2'-race (after 1 h oviposition)	—	20.1	1613	0.83 ± 0.17	1.44 ± 0.12	2.28 ± 0.16
c) 'NB_4D_2' – race (diapuasing)	—	—	—	0.96 ± 0.09	1.98 ± 0.11	2.98 ± 0.12
d) 'NB_4D_2' – race (post–diapause)	—	—	—	0.76 ± 0.09	1.35 ± 0.07	2.14 ± 0.13
e) 'NB_4D_2' – race (acid-treated)	87.04	—	—	1.28 ± 0.12	0.57 ± 0.16	1.93 ± 0.18

[a] Cholesterol equivalents, [b] mean ± SD of 6 samples, [c] mg sterols per g dry leaf.

TABLE 2. Percentage of sterols in the mulberry leaf and silkworm eggs.

Sl. no.	Sterol	Systematic nomenclature[b]	% composition [a]		
			Mulberry leaf	'Mysore pure'	'NB4D2'
1.	Cholesterol	Cholest–5 en, 3 β –ol	–	98.2	96.1
2.	β –Sitosterol	24–ethyl cholest–5, 22 - dien–3 β –ol	86.1	1.2	2.5
3.	Stigmasterol	3 β –hydroxy–24 ethyl 5, 22 cholestadiene	12.7	1.1	0.8
4.	Campesterol	24– methyl choleste 5 en β –ol	0.9	0.5	0.4
5.	Brassicasterol	24–methyl choleste–5 22–dien, 3 β –ol	0.3	traces	0.2

[a] based on measurement of areas under GLC peaks.

[b] in accordance with the IUPAC/IUB, *Arch. Biochem. Biophys.* 136: 13–35 (1970).

campesterol and brassicasterols of the leaf to cholesterol. However, some quantities of these (latter three) sterols are utilized by the moth for formation and incorporation into the egg substance.

The functional role of cholesterol in the eggs of the silkworm is still far from clear. In vertebrate liver, its function may be trifold viz., (a) in the membrane synthesis, (b) in the reactions giving rise to coprostenol, dehydrocholesterol and bile salts, and (c) in steroid hormone syntheses (COOK, 1958). In the egg also, it may be quite possible that the cholesterol reserves are used up for hormone and membrane syntheses as the cleavage and development of the embryo proceed. However, the significance of a high cholesterol level in the eggs of bivoltine ('NB_4 D_2') race, could be attributable to the greater functional demands of the development of the embryo than those of multivoltine ('Mysore Pure') race.

Similarly, the role of esterified cholesterol has not been emphasized in animal tissues (COOK, 1958). It is known that the sterol esters with long-chain fatty acids act as sterol stores in tissues and that the esterification of them is enzymatic (CLAYTON *et al.*, 1964; KIRCHER, 1982). Greater levels of sterol esters in the eggs of bivoltine race than those of multivoltine race, could indicate the existence of sterol-stores in the eggs.

The results further demonstrate that a substantial increase in cholesterol level occurs during diapause. Postdiapausing conditions and acid-treatment of eggs reduce the sterol levels of the egg considerably. It may be concluded from these observations that one of the mechanisms for breaking diapause is the reduction of cholesterol levels of the egg. The increased levels during diapause can be explained only by the synthetic ability of the cells of silkworm embryo.

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RESPONSE OF *COTESIA MARGINIVENTRIS* (CRESSON) (HYMENOPTERA : BRACONIDAE) TO LOW TEMPERARURE IN RELATION TO ITS BIOTIC POTENTIAL[1]

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Studies were carried out on response of *Cotesia marginiventris* (Cresson) to low temperatures viz., 5 and 10°C on their survival, fecundity, longevity and sex-ratio. Freshly formed cocoons and one day old mated adults were stored for 5, 10, 15, 20, 25, 30, 35 and 40 days. Mortality in adult females at 5°C was 2.3, 18.0, 66.0 and 100 percent and at 10°C, 2.0, 13.0, 59.3 and 100 percent for 10, 20, 30 and 40 days of storage. Males were more susceptible to low temperature than females. Percent mortality in cocoon stage at 5°C and 10°C after storage for 10, 20, 30 and 40 days was 17.6, 20.3, 60.6 and 100% and 15.6, 19.3, 51.6 and 81.6%, respectively. Adult longevity and fecundity were reduced significantly after 20 days of storage and longer duration had males preponderance in progeny.

(*Key words*: *Cotesia marginiventris*, low temperature, response)

INTRODUCTION

Cotesia marginiventris (Cresson), an important exotic parasitoid of noctuids was introduced for trials against *Spodoptera litura* (Fabricius), which is a serious polyphagous pest. Biology and host age preference of this parasitoid was studied by JALALI *et al.* (1987). It is imperative to accumulate enough parasitoids so that adequate numbers could be released at appropriate time. LOGINOVA (1984) reported that *Encarsia formosa* Gahan could be maintained at 7–9°C upto 30 days without significant mortality. Similarly, JAYANTH & NAGARKATTI (1985) reported that *Bracon brevicornis* Wesmael could be stored upto 30 days at 5°C. Present study was therefore conducted to determine tolerance of parasitoid to low temperature and the effect of storage on fecundity and longevity and the results are presented in this paper.

[1]Contribution No. 516405 of Biological Control Centre, NCIPM, B'lore–24.

MATERIALS AND METHODS

C. marginiventris was reared in the laboratory on 2nd instar of *S. litura*. The cocoons collected from laboratory, were placed in glass chimney for adult emergence and mating. After mating these adults were placed in glass tubes (15 × 2.5 cm) and were plugged with cotton wool. These were placed in BOD incubators maintained at 5°C and 10°C and 60–70% relative humidity. Similarly, 50 cocoons per tube were also kept simultaneously in BOD incubator at 5°C and 10°C. These tubes were removed after 5, 10, 15, 20, 25, 30, 35 and 40 days. Each treatment was replicated 5 times. Observation on mortality was recorded. From each treatment 5 pairs of surviving adults were collected. Fecundity of stored parasitoids was achieved by releasing one hundred 3 day old *S. litura* larvae on foliage of castor leaves in transparent plastic container (20 × 16 cm) to which 5 mated females of *C. marginiventris* were introduced for 24 hours in one container.

This exposure was repeated daily till females died. A mean value per female was calculated to determine the average fecundity. Observations on longevity and sex-ratio of emerging adults were also recorded. Data collected on different parameters of stored parasitioids were compared with those reared under normal laboratory temperature of 27 ± 1°C and 60–70% relative humidity. Data was analysed by using analysis of variance (Complete randomised design).

RESULTS AND DISCUSSION

The data presented in Table 1 revealed that non-significant mortality occurred when adults were stored at 5°C and 10°C upto 15 and 10 days. Females were more tolerant to low temperature as 0.0, 2.3, 4.3, 18.0 and 45.6% mortality was observed in comparison to 0.0, 4.0, 6.0, 20.0 and 54.0% corresponding mortality of males after storage of 5, 10, 15, 20 and 25 days at 5°C, respectively. Similar trend was also observed at 10°C. Mortality upto 15 days was statistically at par at 5°C. It is clear that cocoon stage is more appropriate for storage as mortality at 5°C after storage of 5, 10, 15, 20 and 25 days was 16.0, 17.6, 19.6, 20.3 and 43.3%, respectively, which is much lower than mortality of adults for same period (Table 1). Similar trend was observed at 10°C. Under room temperature conditions also 15% population failed to emerge from cocoons and this was considered as normal mortality in this parasitoid. High mortality was observed in case of adults and cocoons if stored beyond 25 days. Such high mortality due to increased storage was also reported by EISLER & PLESS (1972) in *Lysiphlebus testaceipes* (Cresson).

TABLE 1. Mortality of *C. marginiventris* at 5° and 10°C[1].

Period of storage (in days)	% mortality at 5°C			% mortality at 10°C		
	Adults ♂	Adults ♀	Cocoons	Adults ♂	Adults ♀	Cocoons
5	0.0	0.0	16.0a	0.0	0.0a	15.0a
10	4.0	2.3a	17.6a	2.0	2.0ab	15.6a
15	6.0	4.3ab	19.6a	4.0	4.0b	15.3a
20	20.0	18.0b	20.3ab	19.0	13.0c	19.3ab
25	54.0	45.6c	43.3b	50.0	36.0d	29.3b
30	88.0	66.0d	60.6c	78.0	59.3e	51.6c
35	100.0	92.0e	81.6d	92.0	82.3b	72.0d
40	100.0	100.0f	100.0e	100.0	100.0g	81.6e
Room temperature	0.0	0.0a	15.0a	0.0	0.0a	15.0a
S Em	—	0.76	1.44	—	0.47	0.96
C D at 5%	—	2.51	4.27	—	1.40	2.85

Treatment means followed by same letter are not statistically different.

[1]Values are mean mortality of five replicates.

Data on fecundity, longevity and sex-ratio is presented in Table 2. Mean fecundity at room temperature was 90.6. Storage reduces fecundity even after storage for 5 days. However, a progeny to 79.0, 68.6 and 50.3 was produced after storage of 5, 10 and 15 days, respectively. A sharp decline was observed beyond 20 days. Longevity of male and female was statistically at par with room temperature upto 15 and 10 days of storage at 5°C. Sex-ratio (male : female) was significantly higher upto 15 days of storage, ratio being 1:0.25, 1-0.20 and 1:0.20 respectively. Increased duration of storage resulted in production of more males. DEBACH & RAO (1968) reported cent percent mortality of sperms in the testis of males and in the spermathecae of mated females of *Aphytis linganannensis* Comp. when stored for 8 hours at 1°C. Similarly JAYANTH & NAGARKATTI (1985) reported decrease in longevity and fecundity with increased duration of storage of adults of *B. brevicornis*. They also reported preponderance of males with increase in the duration of storage. The present results corroborate their findings.

Present study has shown that *C. marginiventris* could be stored for 15 days at 5° and 10°C with significantly affecting its biological parameters. Since developmental time of parasitoid is 8 days large numbers could be stored and made available at appropriate time for field release. The results could be utilised for storage of mass produced parasitoids in the laboratory.

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TABLE 2. Fecundity, longevity and sex-ratio of *C. marginiventris*[1] stored at 5°C.

Period of storage (in days)	Fecundity	Longevity ♂	Longevity ♀	Sex-ratio ♂ : ♀
5	79.0b	6.3a	7.3a	1 : 0.25a
10	68.6c	6.0a	6.3ab	1 : 0.20b
15	50.3d	6.6a	5.6b	1 : 0.20b
20	34.6e	3.6b	4.6bc	1 : 0.10c
25	19.3b	3.0b	3.0c	1 : 0.08c
30	5.3g	3.0b	2.6c	1 : 0.07c
35	1.6g	3.0b	2.0d	1 : 0.0d
Room temperature	90.6a	6.6a	7.6a	1 : 0.27a
S Em	1.35	0.26	0.28	0.01
C D at 5%	4.63	0.78	0.85	0.03

Treatment means followed by same letter are not statistically different.

[1]Values are mean of five replicates.

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IMPACT OF NATURAL AND ARTIFICIAL DIET ON THE FEEDING AND REPRODUCTION IN TWO SPECIES OF ACRIDIDS (ORTHOPTERA : INSECTA)

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Feeding and reproduction in *E.a.alacris* (Ser.) and *O. nitidula* (Wlk.) on natural and artificial diets are discussed. Food consumption and weight gain were higher in individuals reared on the natural host *Panicum maximum* (Poaceae), while they were lower when fed on artificial diet. Longer preoviposition period and lower fecundity were evident in insects reared on artificial diet.

(*Key words*: Food utilization, fecundity, artificial diet, *Eyprepocnemis alacris alacris*, *Oxya nitidula*, *Panicum maximum*)

INTRODUCTION

Phytophagous insects require adequate concentrations of nutritionally important chemical substances like proteins, amino acids, lipids, carbohydrates in their diet for growth and reproduction. Though all phytophagous insects tend to have almost similar qualitative nutritional requirements irrespective of feeding habit, their quantitative intake always varies. As such the biotic potential of insects is influenced by the quantitative intake (SLANSKY, 1982; SLANSKY & SCRIBER, 1985; ANANTHAKRISHNAN *et al.*, 1985, 1986). For optimal nutrition as seen in all food plants, the required nutrients should be available at proportional levels. Studies on the nutritional requirements of several insect species utilizing synthetic diets are well known. Artificial diets developed for European corn borer, *Ostrinia nubilalis* by BECK *et al.* (1949) formed the basis for many insect diets especially in rearing phytophagous insects. DADD (1960) described an artificial diet on which *Schistocerca gregaria* and *Locusta migratoria* could be reared. SINGH (1977) gave a detailed account of diet formulas, diet preparation and rearing procedures for a number of insect species. The present study was carried out to investigate the food consumption, utilization, growth and reproduction in *Eyprepocnemis alacris alacris* and *Oxya nitidula* in relation to natural and artificial diet.

MATERIALS AND METHODS

E. a. alacris and *O. nitidula* were collected from fields and reared in cages. Newly hatched first instar nymphs were separated and one group was fed on *Panicum maximum* and another with artificial diet. Chemically defined diet was prepared according to DADD (1960) (Table 1). Mating pairs were isolated and provided with pots filled with loose wet soil for oviposition. The number of egg pods laid by the female and the number of emerging nymphs were counted.

Gravimetric methods were adopted to study the quantitative aspects of food utilization on both the diets. Weighed pellets or *P. maximum* leaves were provided in separate plastic containers. After feeding for 24 h left over food, excreta and insects were weighed. Consumption index, growth rate and nutritional indices were calculated according to WALDBAUER (1968). The first instar nymphs were avoided for the experiment since they fed very little on both the diets.

TABLE 1. Composition of the diet.

Cellulose powder	15 g
Cholesterol	50 g
Salt mixture*	1.5 g
Sucrose	5 g
White dextrin	5 g
Casein	6 g
Peptone	2 g
Egg albumin powder	2 g
Ascorbic acid	100 m
Water (20% ethanol containing vitamins)	10 ml
Vitamin	
Thiamine	25 μg/g diet
Riboflavin	25 ,,
Nicotinic acid	100 ,,
Pyridoxine	25 ,,
Folic acid	25 ,,
Inositol	250 ,,
Ca. pantothenate	50 ,,
p-amino benzoic acid	25 ,,
Biotin	1 ,,
Choline chloride	1250 ,,
Salt mixture*	
Sodium chloride	22 parts
Calcium phosphate	130 ,,
Pot. citrate	125 ,,
Magnesium sulphate	30 ,,
Iron citrate	5 ,,

RESULTS

Data on the nymphal duration and fecundity of the 2 acridid species on both the diets is given in Table 2. Maximum fecundity and fastest rate of development were observed on

TABLE 2. Influence of artificial and natural diet on the life cycle and fecundity of *E. alacris alacris* and *O. nitidula*.

	Nymphal duration					Adult longevity	No. of egg pods laid	Total no. of eggs	Incubation period
	I	II	III	IV	V				
(i) *E. alacris alacris*									
Artificial diet	5.25 ±0.5 (5–6)	11.0 ±1.0 (10–12)	13.75 ±2.06 (11–16)	19.0 ±1.63 (17–21)	25.2 ±1.78 (23–28)	43.25 ±1.09 (40–44)	51.75 ±1.25 (60–53)	3.25±0.51 (3–4)	105.75±4.5 (100–111)	27.0±1.63 (26–29)
Natural diet	8.75 ±1.25 (7–10)	11.0 ±0.816 (10–12)	12.11 ±1.86 (10–15)	12.0 ±1.63 (10–14)	19.25 ±1.25 (18–21)	57.25 ±1.258 (56–59)	65.5 ±1.7 (65–68)	4.333±0.57 (4–5)	134.0±2.94 (130–137)	27.75±1.258 (27–29)
(ii) *O. nitidula*									
Artificial diet	7.0 ±0.707 (6–8)	9.8 ±0.83 (8–10)	10.28 0±.95 (8–10)	13.0 ±0.81 (11–14)	14.6 ±1.14 (13–16)	36.5 ±1.04 (35–38)	38.14 ±1.34 (36–42)	4.33±0.57 (4–5)	40.7±0.6 (39–43)	30.6±1.14 (29–30)
Natural diet	5.6 ±0.89 (5–7)	8.25 ±1.2 (7–10)	7.25 ±0.5 (7–8)	11.0 ±0.81 (10–12)	12.6 ±1.03 (10–14)	41.4 ±1.14 (40–43)	53.4 ±1.14 (52–55)	5.25 ±0.5 (5–6)	51.7±2.0 (51–54)	29.5±1.29 (29–31)

the natural host *P. maximum*. Prolonged pre-oviposition period was observed in females reared on artificial diets. No significant variation was apparent in the incumbation period of eggs by feeding on the two diets. Tables 3 and 4 provide data on the consumption and utilization of natural host and artificial diet by the various instars as well as adults of *E. a. alacris* and *O. nitidula*. Maximum weight of food ingested by the 2 acridids was from *P. maximum*. The weight gain was also higher on *P. maximum*. Consumption index (CI) and growth rate (GR) showed the general trend of decreasing with the advancement of the nymphal stages. Approximate digestability (AD) of the nymphs fed on artificial diet was comparatively higher than on *P. maximum*. Early nymphal stages showed high efficiency of Conversion of ingested and digested food (ECI, ECD).

TABLE 3. Food utilisation by *Eyprepocnemis alacris alacris* on *Panicum maximum* and artificial diet.

Stage	Food consumed	Wt. gain*	Excreta*	CI	CR	AD	ECD	ECI
(i) *Panicum maximum*								
II	4.005	0.707	1.50	0.703	0.124	62.546	28.223	17.652
III	26.187	8.681	10.821	0.619	0.205	58.681	54.491	33.150
IV	44.544	13.825	19.51	0.564	0.175	56.200	55.224	31.036
V	74.609	24.917	32.991	0.431	0.157	51.781	59.870	33.390
Male	89.25	5.423	38.15	0.435	0.190	57.25	10.454	5.985
Female oviposition period								
I 14 days	122.341	30.185	52.53	0.314	0.094	53.319	52.735	30.092
II 12 days	113.54	31.725	51.932	0.304	0.085	54.261	51.494	27.941
III 13 days	102.154	29.505	47.222	0.287	0.083	53.773	53.711	28.861
IV 14 days	87.252	25.411	40.854	0.250	0.084	53.177	50.400	29.210
(ii) Artificial diet								
II	11.201	2.09	1.616	0.844	0.157	85.572	21.804	18.659
III	25.867	6.430	10.208	0.874	0.217	60.536	41.062	24.857
IV	41.573	7.395	17.322	0.675	0.120	58.333	30.963	17.787
V	94.817	9.501	39.771	0.660	0.091	58.051	23.963	13.910
Male	40.649	5.787	18.615	0.167	0.014	54.205	26.263	14.230
Female oviposition period								
I 19 days	98.621	22.109	52.197	0.241	0.063	47.073	56.240	26.474
II 14 days	89.520	23.051	47.375	0.231	0.059	47.191	54.694	25.749
III 10 days	77.48	19.565	41.932	0.212	0.053	45.880	55.038	25.251
IV 8 days	75.65	18.875	40.523	0.230	0.057	46.433	53.733	24.950

Mean of 5 replicates. * mg dry Wt/day/insect.

TABLE 4. Food utilisation by *Oxya nitudula* on *Panicum maximum* and artificial diet.

Stage	Food consumed*	Wt. gain*	Excreta*	CI	GR	AD	ECD	ECI
(i) *Panicum maximum*								
II	7.761	1.931	33.520	0.821	0.204	54.645	45.531	25.880
III	30.402	6.930	13.275	0.754	0.172	56 335	40.462	22.794
IV	65.130	17.831	31.961	0.854	0.207	50.927	47.728	24.306
IV	116.602	19 665	58.215	0.611	0.103	50 073	33.680	16.865
Male	155.340	10.761	65.190	0.848	0.058	64.471	10.744	6.927
Female: Oviposition period								
I 9 days	162.321	40.901	67.500	0.876	0.220	58.415	43.134	25.196
II 12 days	159.141	40.115	65.821	0.873	0.226	58.639	42.986	25.207
III 11 days	115.288	25.010	55.071	0.775	0.168	52.231	41.533	21.693
IV 13 days	107.755	21.221	53.322	0.769	0.151	50.515	38.985	19.693
(ii) Artificial diet								
II	5.326	11.525	11.170	0.653	0.187	78.032	36.693	28.633
III	33.871	7.208	12.213	0.855	0.182	63.942	33.281	21.280
IV	39.138	7.551	15.335	0.613	0.118	60.818	31.722	19.293
V	68.210	10.250	29.761	0.723	0.090	56.368	26.658	15.027
Male	58.370	9.213	25.250	0.575	0.090	56.741	27.817	15.783
Female: Oviposition period								
I 14 days	107.138	34.051	45.715	0.639	0.203	57.330	55.436	31.782
II 13 days	98.760	31.911	41.305	0.608	0.196	58.176	55.540	32.311
III 10 days	96.002	30.491	42.175	0.607	0.192	56.068	56.646	31.760
IV 10 days	87.610	27.213	35.570	0.608	0.188	59.397	52.292	31.061

Mean of 5 replicates. * mg dry Wt / day / insect.

DISCUSSION

E. a. alacris and *O. nitidula* are polyphagous species with *P. maximum* as its natural host plant. It was observed that the consumption and weight gain by the second instar nymph of *E. a. alacris* was higher on artificial diet compared to natural diet. The percentage of silica in the leaves and the poorly differentiated molar region of the mandibles of the early instar (MURALIRANGAN & ANANTHAKRISHNAN, 1977) tend to reduce the consumption and weight gain in *P. maximum*. But in *O. nitidula* eventhough its host plants colonization is influenced by silica content of leaves (MEERA, 1982) no such decreased consumptiom and weight gain was observed in the present studies. Comparatively higher AD of the 2 acridid species during the nymphal stage fed with artificial diet indicate that

percentage of ingested food that is digested and assimilated is more than in *P. maximum*. In *Schistocerca* where nymphs were provided with various artificial diets or grasses, DADD (1960) found that the artificial diet had high coefficient of digestability when compared with grass. Increase in AD may be for compensating reduced consumption of artificial diet in order to maintain good growth (SLANSKY & SCRIBER, 1985). In addition to this, the higher absorption efficiency in the nymphs than in the adult *E. a. alacris* and *O. nitidula* is in agreement with the report of BEENAKKERS *et al.* (1971) and SMITH (1959).

The efficacy of conversion of ingested food into body substance (ECI) is an indication of the ability of insects to utilize ingested food for growth. In the present study clear decrease in ECI values during the ovipositional period from the nymphal period is due to the fact that during the nymphal period much of the ingested food is used for somatic growth whereas during the oviposition period the nutrients are channeled for the developing oocytes (MORDUE & HILL, 1970). The metabolic efficiency expressed as the efficiency of conversion of digested food to body substance also demonstrated a similar trend. However, the conversion efficiency increased gradually within the nymphal period (SMITH, 1959).

Feeding has profound influence on reproduction. The quantity, quality and rate of food consumed by adult insects influence their fecundity and survival(ELLIS *et al.*, 1956; ENGLEMANN, 1970). Absence of significant variation in the incubation period of the 2 species on artificial diet indicate that it did not influence much on it. Feeding and development in the nymphal stage may also influence the timing of the oviposition in female (MCCAFFERY, 1976). In the present study the reduction in the total egg output and prolonged preoviposition period especially that of *E. a. alacris* fed on artificial diet is probably due to the reduced consumption which results in decreased rate of egg production. CAVANAGH (1963) accounted the absence of Gibberellic acid in artificial diet as the cause for the long interval before egg laying. But VISSCHER (1987) very clearly demonstrated that developmental rate and reproductive performance of *Aulocara elliotti* are related to the concentration of plant growth hormones added to the defined diet. Gibberellic acid (GA) significantly shortened the days the laylaying the first egg pod after adult ecdysis in *Aulocara elliotti* when fed with the highest concentration in the defined diet. Probably the complete absence of any plant growth hormone in the artificial diet used in the present study would be the reason for the prolonged preoviposition period in the acridids.

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STUDIES ON GENE ACTION FOR SOME QUANTITATIVE TRAITS IN SILKWORM, *BOMBYX MORI* L.

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A 7 × 7 diallel cross involving seven inbred lines of silkworm *Bombyx mori* L. and their F_1s including reciprocals were subjected to genic analysis. Proportion of $(H/D)^{\frac{1}{2}}$ revealed partial dominance in respect of all traits except for fecundity and hatching percentage for which over-dominance was noticed. The proportion of positive and negative effects of genes was found unequal for all the traits studied except for pupal weight which had equal number of positive and negative alleles. The KD/KR value indicated predominance of dominant genes than recessive genes for all the traits except for single cocoon filament length for which recessive genes were more compared to dominant genes.

(*Key words*: silkworm, *Bombyx mori*, diallel cross, imbred lines, fecundity, hatching, pupal weight)

INTRODUCTION

Knowledge of the nature of gene action and number of genes controlling the expression of a quantitative trait is of paramount importance to the breeder to have a sound breeding programme. Hence, these are to be studied by the application of highly sophisticated biometrical methods. Diallel technique is one such method employed in the present investigation to determine the degree of dominance and epistasis by components variance method in 7×7 diallel cross. Perusal of available literature revealed no information on adopting on components variance method in silk-worm diallel studies.

MATERIALS AND METHODS

The parental breeds viz., 'Pure Mysore,' 'C. Nichi' (Multivoltines), 'Saniish-18', 'J_{112}', 'J_{122}'. 'Kalimpong-A' and 'NB'_7, (bivoltines) were crossed in all possible combinations to obtain 42 F_1s (including reciprocals). The experiment was laid out in randomised block design with three replications. The rearing technology was as per KRISHNASWAMI (1978).

Observations were recorded on seven quantitative traits namely, pupal weight, pupal duration, moth emergence, fecundity, hatching, single cocoon filament length and denier. The diallel analysis of genetic components of variance in the broader and more inclusive way was carried out by the methods suggested by JINKS & HAYMAN (1953) and HAYMAN (1954 a, b).

RESULTS AND DISCUSSION

The estimates of genetic components D (variance due to additive effect of genes), H_1 (variance due to dominance effect of genes), H_2 (proportion of dominance variance due to positive and negative effect of genes), h_2 (the net dominance expressed as the algebraic sum over all the loci in heterozygous phase in all the crosses), F (proportion of positive and negative effects of genes) and E (error variance) have been presented in Table 1.

The proportions and differences of the genetic parameters, heritability in narrow sense, t_2 test for the validity of hypotheses underlying the diallel model, and also

the correlation coefficients between Yr and (Wr + Vr) have been presented in Table 2.

It is observed from Table 1 that the additive (D) and dominance (H_1 and H_2) components were highly significant for all the traits except for denier for which H_2 was significant only at 5 percent probability level. This indicated the importance of additive and dominance gene effects over all the loci in determining the traits. However, additive component (D) was higher in magnitude compared to dominance components (H_1 and H_2) for pupal weight, pupal duration, moth emergence, single cocoon filament length and denier suggesting predominance of additive effects of genes over dominance effects of genes. High heritability in narrow sense in respect of pupal weight (59.67 percent), pupal duration (95.18 percent), moth emergence (86.92 percent), single cocoon filament length / (57.09 percent) and denier (76.49 percent) also supported predominant role of additive gene action in the inheritance of these traits.

The higher magnitude of dominance than additive component for fecundity and hatching percentage suggested predominance of dominance. Low heritability in narrow sense in respect of fecundity (17.54) percent and hatching (22.16 percent) also indicated predominant role of dominant gene action in the inheritance of these two traits. But JOLLY *et al.* (1965) reported additive gene action for fecundity in *B. mori* while studying the effect of genetic diversity on hybrid performance in multivoltine breeds. The estimates of F were positive and significant for all the traits studied except for hactching and single cocoon filament length, which were non-significant and it was negative for single cocoon filament length.

TABLE 1. Estimation of genetic components of variance with their standard errors in a 7 × 7 diallel set of silkworm.

Components	Pupal weight	Pupal duration	Percentage moth emergence	Fecundity	Hatching percentage	Single cocoon filament length	Denier
D	7.79** ±0.27	1143.00** ±30.58	24.59** ±1.86	2292.00** ±384.08	2.02** ±0.50	52923.80** ±2480.80	0.21** ±0.02
F	1.40* ±0.65	304.70** ±73.37	16.19** ±4.47	2986.00** ±921.39	1.78 ±1.21	—1910.00 ±5951.38	0.13* ±0.06
H_1	6.06** ±0.66	331.61** ±73.63	15.19** ±4.49	13379.15** ±924.66	6.88** ±1.21	34044.14** ±5972.46	0.18** ±0.06
H_2	5.91** ±0.58	251.72** ±64.87	10.93** ±3.95	11377.85** ±814.75	6.28** ±1.07	29835.83** ±5262.57	0.11* ±0.05
h_2	22.07** ±0.39	669.38** ±43.57	0.57 ±2.66	35283.40** ±547.22	25.53** ±0.72	110925.81** ±3534.59	0.01 ±0.03
E	0.15 ±0.10	7.74 ±10.81	1.18 ±0.66	97.10 ±135.79	0.50** ±0.18	956.74 ±877.09	0.005 ±0.009

* : Significant at 5%

** : Significant at 1%

TABLE 2. Proportion and difference of genetic components, heritability in narrow sense and test of significance of diallel hypothesis in silkworm.

Proportions	Pupal weight	Pupal duration	Percentage moth emergence	Fecundity	Hatching percentage	Single cocoon filament length	Denier
$(H_1/D)^{\frac{1}{2}}$	0.88	0.54	0.79	2.41	1.84	0.80	0.93
$H_2/4H_1$	0.24	0.19	0.18	0.21	0.23	0.22	0.15
KD/KR	1.23	1.66	2.44	1.00	1.63	0.99	2.00
h^2/H_2	3.73	2.66	—0.05	3.10	4.06	3.72	0.10
H1-H2	0.15	79.9	4.26	2001.30	0.60	4208.18	0.686
Correlation value between (Wr+Vr) and Yr	—0.98**	0.90**	0.45	—0.89**	—0.95**	—0.71*	—0.48
Heritability (ns)	59.67	95.18	86.92	17.54	22.16	57.09	76.49
t^2	0.95	0.16	0.71	0.16	3.16	0.78	12.72**
't' value for (b—0)	15.99**	11.88**	2.87*	8.15**	5.30**	4.41**	3.16*
't' value for (b—1)	—1.16	—0.61	—0.024	—0.09	—02.50	—1.49	—5.67**

* : Significant at 5%.
** : Significant at 1%.

The estimates of mean degree of dominance $(H_1/D)^{\frac{1}{2}}$ were less than 1.0 (Table 2) for pupal weight (0.88), pupal duration (0.54), moth emergence (0.79), single cocoon filament length (0.80) and denier (0.93) indicating partial dominance. Similar report was made by GAMO & HIRABAYASHI (1983) in respect of filament length. The mean degree of dominance being more than 1.0 for fecundity (2.41) and hatching (1.84) gave an indication of overdominance in controlling the trait. The ratio of $H_2/4H_1$ indicated unequal distribution of positive and negative alleles for all the traits as the ratio was not close to 0.25, except, for pupal weight for which almost equal distribution of positive and negative genes was noticed. The H_1/-H_2 value was not equal to zero in respect of all the traits.

The ratio of KD/KR was more than unity for all the traits except for single cocoon filament length (0.99) which indicated excess of dominant genes than recessive genes. The value of h^2/H_2 indicated 3–4 groups of dominant genes in the control of pupal weight, fecundity, hatching and single cocoon filament length, while it was 2–3 groups of dominant genes for pupal duration and at least one group of dominant genes for denier. The groups of dominant genes controlling moth emergence was inconclusive. GAMO & HIRABAYASHI (1983) also reported 3–4 groups of dominant genes for cocoon filament length.

Correlation value between Yr and (Wr — Vr) indicated that most of the dominant genes have got positive effect i.e.. towards

greater performance, in all the traits, except for pupal duration and moth emergence wherein dominant genes have got a negative effect. Non-significance of t_2 test in respect of all the traits except for denier indicated conformity of the data with the assumptions of the diallel model.

From the foregoing discussion, it is evident that the traits under study in silkworm, *B. mori* are governed by both additive and dominance genetic components for all the traits in different proportions, except for denier wherein additive, dominance and epistatic variances were found to be in operation. Under such a situation improvement in the traits may be expected through reciprocal recurrent selection breeding programme to utilize simultaneously all kinds of gene effects.

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STUDIES ON THE BIOLOGY AND SEASONAL ABUNDANCE OF *HYPENA LACERATALIS* WALKER (LEPIDOPTERA : NOCTUIDAE) ON *LANTANA CAMARA* L. IN INDIA

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Hypena laceratalis **Walker, an indigenous defoliator of** *Lantana camara*, **completed its development in 24.92 ± 3.92 days at 31 ± 1°C and 60–80% RH in the laboratory, with five larval instars. However, 40% of the larvae underwent an additional moult. The females laid an average of 271 eggs per female in a life span of 19.46 ± 6.36 days. The insect was seasonal, occurring during October to February, where the temperature ranges from 26.9 to 14.9°C. The effectiveness of this insect was reduced by larval parasites.**

(*Key words*: *Hypena laceratalis*, *Lanatana camara*, development, parasites, seasonal abundance)

INTRODUCTION

Lantana camara L. (Verbenaceae), of tropical American origin (HARLEY, 1971a), is a serious weed of forests, plantations and waste lands, replacing local vegetation in most parts of the country. In addition to the toxicological problems caused to grazing animals, it has been reported to be detrimental to sandalwood forests through competition and as a symptomless carrier of sandal spike disease (NAYAR & SRIMATHI, 1963).

Hypena strigata (F.) is considered one of the potential natural enemies of *Lantana* in Hawaii, which caused foliar devastation to thousands of acres (DAVIS & KRAUSS, 1962). In India, *Hypena* sp. (nr. *abyssinialis*), later identified as *H. laceratalis* Walker by Commonwealth Institute of Entomology, London (VIRAKTAMATH, personal communication), was found to be quite common on the foliage of *Lantana* in Bangalore, Coorg and Coimbatore (MUNIAPPAN & VIRAKTAMATH, 1986). BEESON & CHATTERJEE (1939) have reported *H. abyssinialis* Gn. (*ignotalis* Wlk.) and *H. striata* F. occurring in Dehra Dun throughout the year, and the latter, often skeletonizing young leaves of *Lantana*.

In the course of a survey conducted by the authors for indigenous natural enemies of *Lantana*, *H. laceratalis* was found to cause considerable defoliation of *Lantana*. The present studies were initiated as very little information was available on this insect or its potential as a biocontrol agent.

MATERIALS AND METHODS

Culture of *H. laceratalis* was maintained in the laboratory. For studies on the developmental stages, freshly laid eggs were collected individually (15 nos.) in 8×2.5 cm, glass vials. The percentage hatch was recorded and larvae were reared on *Lantana* leaves. The number and duration of larval instars (by head capsule measurement), pupal period and adult longevity were recorded.

Fecundity was determined by releasing single pair of adults separately into wooden

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cages (10 cm^3), with brass wire mesh on 3 sides and top and a sliding glass front. A moist sponge was placed covering the wooden base to provide humidity. Adults were fed with 50% honey on cotton swab. A bouquet of *Lantana* twigs (changed daily) was kept as oviposition site and eggs were counted daily.

For studies on seasonal abundance of *H. laceratalis*, 25 twigs of the plant were randomly collected from Hessaraghatta area during 1987–1988 at fortnightly intervals. Number of larvae and eggs were counted and reared up to adult stage in the laboratory for recording of parasites, if any.

RESULTS AND DISCUSSION

The total life cycle was completed in 24.92 ± 3.5 days in the laboratory at 31 ± 1°C and 60–80% RH. The duration and measurements of various stages and fecundity are given in Table 1.

Egg

The eggs are laid singly or in groups of 4–5 on leaves, buds and young twigs. They are round, pale green in colour with striations on the upper surface. Before hatching they turn dark and minute orange spots appear on the chorion.

Larva

Soon after hatching the larva starts feeding on the leaves, by scrapping the upper epidermis and tissues beneath, leaving behind the lower epidermis. The fed areas appear as white patches on the leaves on drying. Initially, the larvae are pale green in colour, gradually turn dark green with age. As they develop, white longitudinal and transverse lines appear, with black spots at the base of the bristles, which are distributed throughout the dorsal surface of the body. The larvae passed through five instars, but 40% of them, irrespective of the sex, underwent a sixth moult before pupation. There seems to be correlation between larval growth and the number of instars, as in larvae that completed development in five instars, the head capsule width was 0.729 mm in IV instar, while in those with six instars, the corresponding width was 0.563 mm (Table 1).

Pupa

Pupation took place at the bases of the jar or among the twigs or leaves in the laboratory. The pupae are dark brown.

Adult

The females laid an average of 271 eggs per female (range 114.0 – 342.3) during their life span of 19.46 ± 6.36 days with a preoviposition period of 3–5 days. Though egg laying was observed throughout the life time, maximum number of eggs were laid during the first week of oviposition.

Seasonal abundance

During the survey, the insect was found to occur in the field during October – February, where the temperature ranged between 26.9 – 14.9°C after which no eggs or larvae could be collected. Even though *H. laceratalis* occurs seasonally in South India, *H. abyssinialis* was found to occur throughout the year, with 9 generations per year, at Dehra Dun (Beeson & Chatterjee, 1939). It thus appears that temperature could be a limiting factor in the development and occurrence of *H. laceratalis*.

Natural enemies

Two ichneumonid parasites, *Casinaria* sp. and *Enicospilus xanthosephalus* Cameron were recorded from early and late larval instars. The percentage parasitism was found to range between 8 and 20%. No egg parasites were recorded.

TABLE 1. Biology of *Hypena laceratalis* under laboratory condition in Bangalore.

Stage	* Duration (days) ± SD	* Measurement (mm)
Egg	4.19 ± 0.66	0.0325
Larva		
I instar	2.88 ± 0.344	0.173
II instar	2.31 ± 0.48	0.277
III instar	2.25 ± 0.58	0.406
IV instar	2.69 ± 0.79	Larvae requiring V instars 0.729
		Larvae requiring VI instars 0.563
V instar	3.50 ± 0.89	Larvae requiring V instars 1.01
		Larvae requiring VI instars 0.81
VI instar	4.57 ± 0.98	Larvae requiring VI instars 1.08
Total	15.63 2.31	—
Pupal	9.29 1.26	
Sex ratio (♀ : ♂)	1 : 0.6	1:05 (in the Field)
Adult longevity	19.46 ± 6.36	
Average fecundity	271 eggs/♀ (ranges (114 = 324 eggs/♀)	

* Average of 15 observations

Impact on the plant:

H. laceratalis does not appear to be a potential biocontrol agent of lantana, as it is seen in the field only in October, by which time the weed is already well established, after commencement of rains in June. Parasitism also takes its toll in further reducing the effectiveness of the insect. Similar observations, for the ineffectiveness of *H. strigata* could be due to parasites in Australia, was made by HARLEY (1971). However, it is likely to perform better in areas with cooler climates, if natural enemies are not present.

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DEVELOPMENT, RELATIVE PROPORTIONS AND EMERGENCE OF *ENCARSIA TRANSVENA* (TIMBERLAKE) AND *ERETMOCERUS MUNDUS* MERCET, IMPORTANT PARASITOIDS OF *BEMISIA TABACI* (GENNADIUS)

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The developmental period, proportions and emergence of *Encarsia transvena* (Timberlake) and *Eretmocerus mundus* Mercet on *Bemisia tabaci* (Genn.) was studied during 1987-1989. The developmental period from egg to adult emergence of *En. transvena* was shorter (12.89 ± 2.71 days) than *Er. mundus* (16.56 ± 2.69 days). The shortest and longest period was 7 and 25 days for *En. transvena* and 12 and 28 days for *Er. mundus*, respectively. *En. transvena* predominated (70.1%) over *Er. mundus* (29.9%) throughout the cotton season. The adult emergence in both the species occurred high (78.18-94.50%) in humid months (August–September), while it was suppressed (42.33–60.00%) in cold months (November-January). The adult emergence was higher in *En. transvena* than *Er. mundus*. The high population of *En. transvena* females occurred in September-October. The seasonal average ratio of females and male in *En. transvena* was 6.24:1, and 1.66 : 1 in *Er. mundus*.

(*Key words*: seasonal emergence, sex ratio)

INTRODUCTION

Encarsia transvena (Timberlake) and *Eretmocerus mundus* Mercet (Aphelinidae: Hymenoptera) were found most dominant amongst 6 aphelinid parasitoids recorded on the cotton whitefly, *Bemisia tabaci* (Gennadius) under Parbhani conditions of Maharashtra State. The biological studies on *En. lutea* Masi and *Er. mundus* on *B. tabaci* have been conducted in Sudan, Israel, Jordan and Egypt (GAMEEL, 1969; FOLTYN & GERLING, 1984; BULTER, 1986; ABDEL-FATTAH *et al.*, 1987). From India, *Er. mundus* (=*Masi* Silvestri) (SAMUEL, 1950) and *En.* (=*Prospaltella*) *lutea* Masi (THAKRE *et al.*, 1986) have been reported as parasitoids of *B. tabaci*. However, its biology has not been studied on whitefly *B. tabaci*. Therefore, the present studies were conducted to determine the developmental period, relative proportions and emergence of both the species.

MATERIALS AND METHODS

Collections of *B. tabaci* nymphs were made weekly from the unsprayed cotton field at Cotton Research Station, Parbhani during two seasons, 1987–1989. They were reared in the laboratory till the emergence of adult parasitoids and were preserved. Later on they were counted and sorted out specieswise under the microscope, on the basis of the antennal club segments as described by C.A.B. International Institute of Entomology, London. The percentage proportion of each species was then worked out on the basis of total adult parasitoids. The female–male ratio in each species was also recorded in the collections made during the season of 1987–1988.

To determine the percentage emergence of adult parasitoids, the parasitized pupae were collected each month from the field during

1988–1989 and separated specieswise on the basis of its pupal colour *i.e.*, black in *En. transvena* and chocolate in *Er. mundus*. They were kept separately in the glass tubes until the emergence of parasitoids.

For determining the developmental period from egg to adult emergence, 15 adults of each species were exposed in a plastic cage (11 × 9.5 cm diameter) fixed on cotton plant with a single leaf, infested with 2nd and 3rd instar host nymphs which were previously protected from the parasitoid attack. The parasitoids were removed from the cage after 24 hours. The parasitized pupae were observed daily to record the time of parasitoid emergence. These studies were done under field conditions at different periods of the season. The data obtained on the developmental period, proportion, emergence and sex ratio of both the species are presented in Tables 1, 2 and 3.

RESULTS AND DISCUSSION

Developmental period:

Both the speceis preferred 2nd or 3rd instar host nymphs for oviposition beneath the host. The grub of the parasitoid fed internally on the substance of the whitefly nymph and finally killed it. The parasitoid pupated inside the host body which markedly swelled. Both the species were solitary parasitoids on host, giving rise to one adult parasitoid only.

The period for egg to adult emergence in *En. transvena* was found to increase (8.07 ± 0.97 — 18.68 ± 3.39 days) with the advancing of season (September–January). The shortest and longest period was 7 and 25 days, respectively. In case of *Er. mundus*, the developmental period was observed to decrease (17.08 ± 2.07 — 15.91 ± 1.8 days) with the advancing of season (November–January). The shortest and longest period was 12 and 28 days, respectively. Thus the developmental period of *En. transvena* was shorter than *Er. mundus* (Table 1). It was observed that the development was influenced by temperatures. The increased temperature had shortened the development of *En. transvena* and it was just reverse in case of *Er. mundus*.

In the laboratory, it was also observed that adults of both the species survived for 2–6 days though adult life span of *En. transvena* was slightly shorter (2.95 ± 1.13 days) than *Er. mundus* (3.05 ± 0.63 days).

TABLE 1. Developmental period of *Encarsia transvena* and *Eretmocerus mundus* on cotton at different period.

Date of study	Temperature (°C)	Relative humidity (%)	Duration in days	
			Encarsia transvena	*Eretmocerus mundus*
11–9–87 to 21–9–87	28.9±6.9	61.5±9.7	8.07±0.97 (7±10)* (94)**	—
24–11–87 to 12–12–87	21.4±8.4	62.5±7.0	10.55±2.53 (8±17) (172)	17.08±2.07 (12—22) (126)
4–12–87 to 24–12–87	19.4±9.2	61.3±7.4	14.25±3.96 (14±19) (58)	16.68±4.19 (14—28) (40)
31–12–87 to 26–1–88	21.1±1.3	53.3±1.6	18.68±3.39 (15±25) (48)	15.91±1.80 (14—24) (84)
Average:			12.89±2.71 (7—25)	16.56±2.69 (12—28)

* Range ** Numbers observed (—) Not studied

HUSAIN & TREHAN (1933) reported that an unidentified parasitoid of *B. tabaci* (*gossypiperda* M. and L.) completed its life-cycle within 6–7 days in August. GAMEEL (1969) reported the total developmental period to be 21–24 days for *En. lutea* and 28–32 days for *Er. mundus* at 27–30°C. He further reported that the life of *En. lutea* was longest (14–30 days) in December. The complete development of *Er. mundus* lasted for 18 days at 30°C and 26 days at 19°C (TAWFIK *et al.*, 1983). According to FOLTYN & GERLING (1984) the development at 25°C was 17 days for *En. lutea* and 23.5 days for *Er. mundus*. BUTLER (1986) reported the developmental periods of 17.8 ± 1.2 and 15.8 ± 1.8 days for *Er. mundus* at 25.0 and 27.5°C, respectively. ABDEL-FATTAH *et al.* (1987) observed the developmental period of *En. lutea* to be 15 days on sweet potato and adult life span to be 3.7–8.3 days at 28°C.

Relative proportions:

The data presented in Table 2 revealed that *En. transvena* predominated over *Er. mundus* throughout the cotton season. In September *Er. mundus* completed (46.2%) with *En. transvena* (53.8%), but it declined in October (18.2%) and later on it reached a good proportion in January (44.1%). GAMEEL (1969) found that *En. lutea* dominated (66%) over *Er. mundus* (34%). FORER & GERLING (1984) found *Er. mundus* dominating *En. lutea* in early season, while *En. lutea* dominated in later season.

Adult emergence:

The data presented in Table 3 indicated that the percentage emergence of adult was higher in *En. transvena* than *Er. mundus* in the season except January. The maximum emergence (88–95%) in both the cases was noticed in the humid months (August–September) and thereafter, it decreased gradually from October to January (89.50–43.33% in *En. travnsena* and 71.11–49.00% in *Er. mundus*). In January, the emergence was depressed by about 50 percent as compared to emergence in humid months.

Sex ratio:

Encarsia transvena females predominated to males throughout the season. The female population was higher during September and October (7.84–9.17 females: 1 male).

TABLE 2. Percentage proportion of *Encarsia transvena* and *Eretmocerus mundus* in different months during the cotton seasons, 1987–1989.

Month	Proportion (%)							
	1987–1988			1988–1989			Average	
	No. examined	*Encarsia transvena*	*Eretmocerus mundus*	No. examined	*Encarsia transvena*	*Eretmocerus mundus*	*Encarsia transvena*	*Eretmocerus mundus*
September	435	53.8	46.2	424	74.3	25.7	63.9	36.1
October	539	81.8	18.2	515	76.3	23.7	79.1	20.9
November	556	79.1	20.9	527	78.6	21.4	78.9	21.1
December	517	78.1	21.9	621	57.8	42.2	67.0	33.0
January	243	70.4	29.6	404	55.9	44.1	61.4	38.6
Mean	2290	72.6	27.4	2491	68.6	31.4	70.1	29.9

TABLE 3. Sex ratios and adult emergence of *Encarsia transvena* and *Eretmocerus mundus* in different months during the cotton season, 1988-1989.

Month	Adult emergence (%)				Sex ratio (F:M)			
	No. observed	*Encarsia transvena*	No. observed	*Eretmocerus mundus*	No. examined	*Encarsia transvena*	No. examined	*Eretmocerus mundus*
August	200	94.50	90	87.78	105	6.00:1	120	1.22:1
September	300	92.33	110	78.18	234	9.17:1	201	1.39:1
October	400	89.50	180	71.11	441	7.84:1	98	1.23:1
November	600	76.33	600	52.67	440	5.20:1	116	1.18:1
December	250	59.20	200	50.50	404	5.03:1	113	2.14:1
January	300	42.33	300	49.00	171	4.18:1	72	2.78:1
Mean		75.70		64.87		6.24:1		1.66:1

It decreased with the advancing of the season. In case of *Er. mundus*, females predominated to males but at low proportion, however, the female population was doubled to male population in December and January (Table 3). SHARAF & BATTA (1985) reported that temperature affected the sex ratio of *Er. mundus*.

GERLING *et al.* (1982) observed *En. lutea* and *Er. mundus* as hyperparasitoids of each other in Israel. In the present study, the decreased female population in *En. transvena i.e.*, December and January as compared to *Er. mundus* might be due to the hyperparasitic habit of *Er. mundus* on *En. transvena*; however, it needs support of experimental finding.

The studies concluded that the development and emergence of *Er. mundus* was inferior to *En. transvena*. *En. transvena* dominated over *Er. mundus* throughout the cotton season. The percentage emergence of parasitoid adults in both was high during the humid months.

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EVALUATION OF SOME NEWER INSECTICIDES FOR THE CONTROL OF THE SWEET POTATO WEEVIL, *CYLAS FORMICARIUS* FAB.

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Seven insecticides namely fenvalerate (0.03%), decamethrin (0.003%), heptachlor, chlordane and fenthion each at 0.05% concentration and sevimol (carbaryl + molasses) 0.1% were tried against sweet potato weevil, *Cylas formicarius* Fab. for three seasons in 1982-1983. Among them the synthetic pyrethroids viz., fenvalerate, permethrin and decamethrin were found to be the most effective insecticides in reducing weevil infestation and thereby increasing the yield of marketable tubers.

(*Key words*: sweet potato weevil, *Cylas formicarius*, control with synthetic pyrethroids)

INTRODUCTION

In India, sweet potato, *Ipomoea batatus* is grown over an area of 0.17 million hectares with a total production of 1.45 million tons of tubers. The average yield rate of the crop in India is very low mainly due to infestation by the sweet potato weevil *Cylas formicarius* Fab. It is the most common and widespread pest of sweet potato occurring both in the field and in store causing very severe damage. In the field the pest damages the crop throughout the year and attacks all plant parts. Tuber damage varies from 10 to 100 percent (PILLAI *et al*, 1981; RAJAMMA, 1983 a; RAJAMMA & PREMKUMAR, 1984). As the immature life stages of the insect are completed inside the plant parts, control is often difficult. Efficacy of different insecticides like fenthion, carbaryl, fenitrothion, monocrotophos, quinalphos, endosulfan, ekalux and aldrin have been reported by various workers (SUBRAMANIAM *et al.*, 1973; JAYARAMAIAH, 1975; JOHNSON *et al.*, 1979; PILLAI *et al.*, 1981; RAJAMMA, 1983 b; RAJAMMA, 1985). In the present studies field evaluation of some newer insecticides including three pyrethroids has been made and the results reported.

MATERIALS AND METHODS

The field experiments were conducted at the Central Tuber Crops Research Institute, Trivandrum during three seasons in 1982–1983, adopting a randomised block design with eight treatments and three replications. The variety used was Kanjhangad local. Ridge method of planting was used with a plot size of 3 × 2.4 sq.m. Recommended manurial practices were followed. Relative efficacy of seven proprietory insecticide formulations was evaluated (Table 1). The planting materials were dipped in the insecticide emulsions for 10 minutes before planting. For spraying 1000 l of insecticide solution was used per hectare. Three sprayings were given for each insecticide treatment, first application being 30 days after planting and the subsequent two at triweekly intervals. Harvest of tubers was done 105 days after planting. Assessment of results was done based on yield of good quality tubers and percentage of damaged tubers on weight basis.

RESULTS AND DISCUSSION

As is evident from Table 1, the weevil damage to the tubers was least (6.2%) in plots

TABLE 1. Effect of insecticides on control of damage to sweet potato tubers caused by *C. formicarius*.

Insecticide formulations	Concentration of insecticide (ai percent)	Mean percentage damage of tubers in different seasons			Mean tuber damage (%)	Good tuber yield (t/ha)	Increase in yield over control (%)
		January – April 1982	July – October 1982	November – February 1982–1983			
fenvalerate (Sumicidin 20 EC)	0.03	5.1 (13.2)	4.7 (12.4)	8.7 (17.3)	6.2	15.6	218.3
permethrin (Ambush 50 EC)	0.03	6.7 (15.0)	6.2 (14.4)	12.5 (20.6)	8.5	15.1	200.8
decamethrin (Decis 2.8 EC)	0.003	3.3 (10.3)	5.8 (13.9)	11.4 (19.4)	6.8	14.7	200.0
heptachlor 20 EC	0.05	58.7 (49.7)	45.5 (42.4)	65.3 (53.8)	56.5	5.6	14.3
chlordane (Chlorotox 20 EC)	0.05	55.3 (48.0)	46.4 (42.9)	62.8 (52.5)	54.8	5.4	10.2
carbaryl + molasses (Sevimol 40 EC)	0.1	46.7 (43.1)	42.3 (40.6)	59.7 (50.7)	49.6	6.1	24.5
fenthion (Lebaycid 80 EC)	0.05	18.8 (25.8)	15.2 (23.0)	20.1 (26.6)	18.3	12.0	145.0
control	—	65.8 (54.2)	53.3 (46.9)	67.3 (55.1)	62.1	4.9	—
C.D ($P = 0.05$)	—	(6.7)	(8.1)	(5.4)		(2.9)	

Figures in parentheses are transformed values.

treated with fenvalerate which was on par with decamethrin (6.8%) and permethrin (8.5%) and was significantly superior over fenthion (18.3%) and other treatments. Fenthion was superior to control. Sevimol (carbaryl + molasses), chlordane and heptachlor (49.6 to 56.5%) were ineffective and were almost on par with control (62.1%).

The difference in yield of good quality tubers due to the treatments was also significant and all the three pyrethroid insecticides were significantly superior to fenthion and other treatments. The highest yield of 15.6, 15.1 and 14.7 tonnes/ha were obtained from the fenvalerate, permethrin and decamethrin treated plots and were significantly superior to all other treatments. Among the other treatments, fenthion gave significantly higher yield (12.0 t/ha). All the other insecticides viz. heptachlor, chlordane and carbaryl + molasses were on par and ineffective. The percent increase in yield over control was 145.0 in fenthion, 200.0 in decamethrin, 200.8 in permethrin and 218.3 in fenvalerate treated plots.

Synthetic pyrethroids have been reported by many workers to give quick knockdown effect, longer persistence and greater safety coefficient for mammals, parasites and predators (ELLIOT *et al.*, 1973; BREESE, 1977; IHOSTE, 1977; CARTER & CHADWICK, 1978; WADDILL, 1978; DHINGRA *et al.*, 1979;

RAJAMMA, 1984). Thus the present studies have indicated that pyrehroid insecticides do reduce infestation by *C. formicarius* and produce more marketable tubers.

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NATURAL SUPPRESSION OF MEALYBUGS IN GUAVA ORCHARDS

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Studies on the natural suppression of mealybugs in guava orchards revealed the presence of one parasitoid and four predators on the citrus mealybug *Planococcus citri* (Risso) and a parasitoid and one predator on the striped mealybug *Ferrisia virgata* (Ckll.). The green lacewing, *Chrysopa lacciperda* (Kimmis) the lycaenid *Spalgis epius* Westwood and the coccinellid *Cryptolaemus montrouzieri* Muls. reduced the populations of *P. citri*, while *F. virgata* was checked by the activity of the encyrtid *Blepyrus insularis* Cam. and *S. epius*.

(*Key words*: *Planococcus citri*, *Ferrisia virgata*, natural suppression, guava)

In recent years, the mealybugs *Planococcus citri* (Risso) and *Ferrisia virgata* (Ckll.) have become serious pests on guava in India. In general, most of the mealybugs are regulated by parasitoids and predators in nature (MANI, 1986). The present study investigates the role of parasitoids and predators in the suppression of *P. citri* and *F. virgata* in guava orchards.

Observational studies were made in two localities around Bangalore to determine the impact of naturally occurring parasitoids and predators on the population of *P. citri* and *F. virgata* in 1987. One orchard with severe infestation of *P. citri* at Honnenahalli where insecticides were frequently sprayed, was selected. After the suspension of insecticidal sprays in mid-August, the population of *P. citri* and its natural enemies were observed at fortnightly intervals upto 20th Oct. on 10 randomly selected trees. In each, 4 shoots were chosen (one from each direction) for recording the population. Guava plants with severe infestation of *F. virgata* was selected at IIHR Farm and observations were recorded as in *P. citri*.

Contribution No. 141/89 of IIHR.

At Honnenahalli Farm, *P. citri* appeared in July 1987 on guava trees, and became serious by August presumbably due to the frequent applications of insecticides namely quinalphos (0.05%), methyl parathion (0.05%) and monocrotophos (0.05%). Initially, the mealybug population ranged from 984 to 3401 per tree with a mean of 1420 and the population of the natural enemies was nil (Table 1). After suspension of insecticidal applications, the following natural enemies like *Chrysopa lacciperda* Kimmis, *Spalgis epius* West wood and *Cryptolaemus montrouzieri* Muls. appeared. Among them, *L. dactylopii* was an exotic one recovered in the present study and others were general predators of *P. citri*. The peak population of the green lacewing *C. lacciperda* ranged from 17 to 21 on 5th September while *C. montrouzieri* and *S. epius* ranged from 8 to 13 and 3 to 7 per tree respectively, on the same day. They had reduced the mealybug population to 21.7 per tree on 27th Sept. (ie., 45 days after the suspension of insecticidal applications). The usefulness of green lacewings (*Chrysopa* spp.) and the Coccinellid, *C. montrouzieri* in the control of *P. citri* had been demonstrated by DOUTT (1955) and BARTLETT (1957).

TABLE 1. Population of *P. citri* and its natural enemies at Honnenahalli Farm.

Date of observation	Mean population per plant ± SD			
	Mealybug	Natural enemies		
	P. citri	*Chrysopa*	*Spalgis*	*Cryptolaemus*
5.8.87	1420.6±80.25	0.8±0.15	0	0
20.8.87	962.4±78.68	4.5±1.82	3.4±1.27	2.5±0.74
5.9.87	267.8±49.18	19.4±5.36	6.5±5.36	10.7±2.78
20.9.87	21.7±16.45	8.1±1.84	2.6±1.23	3.2±1.53

SD = Standard deviation.

TABLE 2. Population of *F. virgata* and its natural enemies at IIHR Farm.

Date of observation	Mean mealybug population per plant	Natural enemies	
		Mean *Spalgis* larvae/ plant	Percent parasitism by *Blepyrus*
14.8.87	660.2±82.19	1.80±1.45	3.17±1.12
28.8.87	341.8±49.15	4.90±2.90	18.75±3.50
12.9.87	4.2±2.63	3.10±2.80	38.78±7.46
27.9.87	0.4±0.12	0.10±0.02	42.20±10.15

At IIHR Farm, severe infestation of *F. virgata* was observed by the middle of August with a mean population of 660.2 per plant. Subsequent observations indicated the activity of the encyrtid *Blepyrus insularis* Cam. and *S. epius*. The effect of these two natural enemies on *F. virgata* is presented in Table 2. The peak activity of *S. epius* was observed on 28th August, 1987 with a mean population of 4.90 per plant. The parasitism by *B. insularis* increased progressively to 42.20% in the present study. These two biocontrol agents reduced the mealybug population within a month (Table 2). The activity of *S. epius* in Bangladesh and *B. insularis* in Philippines on *F. virgata* have been documented earlier by JALIL & KABIR (1972) and OTANES (1935), respectively.

In both the studies there was not much variation in the meterological parameters like temperature, humidity rainfall etc. during the investigation period. Hence the natural control of the mealybugs was attributed mainly due to the action of parasitoids and predators.

The authors are thankful to Director IIHR for providing facilities to conduct the study.

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BRIEF COMMUNICATION

TEA MOSQUITO (*HELOPELTIS ANTONII*) FEEDING AS A PREDISPOSING FACTOR FOR ENTRY OF WOUND PATHOGENS IN CASHEW[1]

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The shoot-die back in cashew was investigated. In addition to feeding injury caused by *Helopeltis antonii* Sign., a fungus viz. *Botryodiplodia theobromae* was also isolated consistently from the dead tissues. The primary cause for entry and establishment of the pathogen seemed to be infestation of the insect. Controlled experiments revealed that die-back occurred only when the fungus was inoculated in the lesion caused by feeding of *H. antonii*.

(*Key words*: shoot die-back, cashew, *Helopeltis antonii*, *Botryodiplodia theobromae*)

Cashew (*Anacardium occidentale* L.) is a tree crop of considerable economic importance in Kerala and many other States of India. Over fifty species of insects have been reported to be associated with this tree crop in India (ABRAHAM, 1958; PILLAI et al., 1976; HARI-BABU et al., 1983) of which *Helopeltis antonii* Sign. (Heteroptera : Miridae) ranks first as the major pest.

During extension work on plant protection in cashew plantations raised by the Forest Department, die-back of young shoots and branches was more prevalent, especially in younger plantations. In addition to the damage caused by *H. antonii*, two fungal pathogens were also isolated from the affected tissues. Hence the present study was undertaken to find out the insect-fungal interaction in the manifestation of shoot die-back in cashew.

Field observations were made in a 8-year-old cashew plantation at Vellikulangara in Chalakudy Forest Division, Kerala. Casual observations were also made on isolated trees and in another young planatation at Kurishumudi in Malayattoor Forest Division. During each visit to the plantation, the presence/feeding damage by *H. antonii* as well as incidence of die-back were monitored. The dead/dying twigs were collected, brought to the laboratory and the fungal pathogens isolated.

Controlled experiments were undertaken to confirm the interrelationship between insect feeding and the fungus in causing the shoot die-back. Field collected early fifth instar nymphs of *H. antonii* were used for the experiment. Known number of nymphs were released on to young shoots of 8-month -old cashew seedlings kept in field cages. By next day, the fungal inoculum containing conidia and mycelial mixture was applied on to the lesions caused by insect feeding, using a brush. The other treatments included seedlings fed by *H. antonii* alone; seedlings with pin-pricks alone and seedlings with pin-pricks and subsequent application of fungal inoculum. There were 5 seedlings each for the above treatments and these were observed for about a month.

[1]KFRI Scientific paper No. 197.

H. antonii infestations was present in the field almost throughout the observation period (October 1987 to August 1988) in varying intensity. The population was sparse during June-July 1988. The fungal pathogen isolated consistently from the dead shoots was *Botryodiplodia theobromae* Pat. with rare occurrence of *Colletotrichum gloeosporioides* Penzig. Field observations indicated that the fungus, *B. theobromae* has invaded the branches which had been fed by *H. antonii*.

The isolate of the fungus, *B. theobromae* alone was used for the controlled experiments. Table 1 shows the results of these experiments. All the seedlings fed by *H. antonii* showed necrotic lesions and in due course of time, the tissues around dried up in all cases. Seedlings which were injured by pin-pricks did not show any disease symptoms. All the seedlings inoculated with the fungus, after insect feeding showed symptoms of die-back and death of the shoots from top to bottom in a gradual manner. However, seedlings inoculated with fungus through pin-pricks did not show symptoms of dieback even after six months.

It is well established that the feeding of *H. antonii* results in the formation of lesions in the tender shoots, panicles and immature fruits and subsequent drying up of the area. (SATHIAMMA, 1977 ; AMBIKA & ABRAHAM, 1979). It is also often quoted that the bug while sucking the sap introduces a toxic substance into the plant tissue along with the saliva, resulting in the death of the tissue. But biochemical investigations on this aspect are lacking. NAMBIAR et al. (1973) showed that *H. antonii* was the primary cause for inflorescence blight and the fungi isolated were only saprophytic in nature. It is also supposed that the floral shoot die-back of cashew seen in Nigeria may be due to injury caused by insects and subsequent entry of the fungus, *B. theobromae* (OLUNLOYO & ESURUOSO, 1975). The present investigation shows that insect feeding acts as a predisposing factor for the entry of the fungus and later results in the die-back of the shoots. The fungus may be surviving and multiplying as a saprophyte on the necrotic and moribund plant tissues formed by the feeding of the insect, and subsequently attacking the woody tissues. The ability of the fungus to perennate over dead tissues and turn pathogenic during favourable environment is documented earlier in *Albizia* plants (SHARMA & SANKARAN, 1988). Further in-depth studies will be useful in elucidating the role of the fungus, *B. theobromae* and the tea mosquito in the development of shoot die-back in cashew.

TABLE 1. Incidence of shoot die-back in cashew due to *H. antonii* and the fungus, *B. theobromae*.

S. no.	Treatment	Total no. of seedlings	Incidence of die-back
1.	Seedlings fed by *H. antonii*	5	Nil
2.	Seedlings with pin-pricks	5	Nil
3.	Seedlings inoculated with the fungus, after insect feeding	5	5
4.	Seedlings inoculated with the fungus, after making pin-pricks	5	Nil

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BRIEF COMMUNICATION

SUSCEPTIBILITY STATUS OF MALARIA VECTORS *ANOPHELES CULICIFACIES* AND *ANOPHELES STEPHENSI* (DIPTERA : CULICIDAE) TO DDT, DIELDRIN AND MALATHION

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The susceptibility status of malaria vectors *Anopheles culicifacies* and *Anopheles stephensi* to DDT, BHC and malathion were studied in Haryana State. The corrected mortality in the case of DDT in Jind and Bhiwani districts was 26.32% and 20.6% respectively in the field collected *Anopheles culicifacies*. The mortality ranged between 4.5%-35% in all the district to DDT against *Anopheles stephensi*. The corrected mortality for *Anopheles stephensi* was reported 15%, 18.75% and 27.5% for Dieldrin in Ambala, Kurukshetra and Karnal districts.

(*Key words*: *Anopheles culicifacies*, DDT, dieldrin, malathion)

Large scale use of insecticides in public health and agriculture, deforestation, extension of irrigation facilities to bring more areas under cultivation and lack of water management have changed the ecology in many areas of the country. The mosquito resistance may have been affected due to the change in ecology. Therefore there is an urgent need to take up entomological studies particularly in hard core areas of malaria regarding status of adult susceptibility to insecticides. In 1946, DDT resistance was first discovered in the housefly from Sweden (WEISMANN, 1947). In India the first report of appearance of DDT resistance in *Culex fatigans* was observed in a village in Delhi state where the houses had been treated with DDT for the preceding six years (PAL et al., 1952) Among the malaria vectors *Anopheles stephensi* was the first to be noticed to have developed resistance in 1955 to DDT in Erode town (RAJGOPAL et al., 1956). RAHMAN et al. (1959) observed the DDT resistance in *Anopheles culicifacies* in Gujarat state. DAS (1966) reported the HCH resistance first time in *Anopheles aconitus* and *Anopheles nigerrimus*. Resistance to malathion in *Anopheles culicifacies* was found in Gujarat state (RAJGOPAL, 1977). The present field study on susceptibility status of DDT, dieldrin and malathion of malaria vectors was carried in Haryana State.

The study was carried out in different districts of Haryana state. The susceptibility test of the vectors were carried out by WHO kit. The method descirbed by BROWN & PAL (1971) was adopted in the study. The adult female mosquitoes were collected by an aspirator tube from the field and transferred to a plastic holding tube. A plastic exposure tube lined with insecticide impregnated papers was then connected to the holding tube and the mosquitoes were transferred to the former through a hole in the plastic slide between the two tubes. The slide was closed and exposure tube was allowed to stand upright, the gauze-covered an uppermost for the exposure period. After the exposure for an hour, the mosquitoes were transferred to the holding tube, which was allowed to stand upright for 24 hours with a piece of moist cotton wool on the gauze end. Mortality counts were made at the end of the 24 hours period and mosquitoes unable to walk counted

as dead. Papers impregnated with various concentrations, DDT (4.0%), dieldrein (0.4%) and malathion (5%) were used.

Susceptibility tests were carried out exposing *Anopheles culicifacies* and *Anopheles stephensi* adults to DDT, Dieldrin and malathion impregnated papers for one hour and mortality counts were made after 24 hours. (Table 1). Result revealed that there was 26.32% and 20.6% correct mortality in the case of DDT in Jind and Bhiwani districts respectively in the field collected *Anopheles culicifacies*. The mortality ranged between 4.5%–35% in all the districts to DDT against *Anopheles stephensi*. The corrected mortality for *Anopheles stephensi* 15%, 18.75% and 27.5% for dieldrin was reported in Ambala, Kurukshetra and Narnaul districts. The field tests clearly suggests that there was a rapid build up of resistance in *Anopheles stephensi* and *Anopheles culicifacies*. It may be pointed out that the first instance of malathion resistance in *Anopheles stephensi* in Haryana state was reported in 1984 (SUBBARAO et al., 1984). MANOUCHEHRI et al., (1974–1975) reported the malathion resistance in *Anopheles stephensi* after continuous spray of 10 years in Iran. While RATHOR & TOQIR (1980) in Pakistan observed resistance within 3 years. In Sonepat district, malathion was used to control epidemic of

TABLE 1. Susceptibility status of *Anopheles culicifacies* and *Anopheles stephensi* to DDT, dieldrin and malathion in Haryana State.

District	Insecticide tested.	Mosquito species			
		Anopheles culicifacies		*Anopheles stephensi*	
		No.	% corrected mortality	No.	% corrected mortality
Ambala	DDT 4%	40	30%	40	15%
	DLN 0.4%	40	10%	40	15%
	MLN 5%	40	100%	23	73.9%
Kurukshetra	DDT 4%			40	25%
	DLN 0.4%			40	18.75%
	MLN 5%			40	100%
Bhiwani	DDT 4%	40	20.6%		
	DLN 4%	60	19.53%		
Jind	DDT 4%	40	26.3%		
	DLN 0.4%	40	2.63%		
Sonepat	DDT 4%			30	20%
	MLN			75	100%
Narnaul	DDT 4%			40	35%
	DLN 0.4%			40	27.5%
Gurgaon	DDT 4%	21	23.7%		
	DLN 0.4%	40	100%		
	MLN 5%	40	100%		
Karnal	DDT 4%			40	20%
	DLN 0.4%			40	22.5%
	MLN 5%	30	100%	70	100%

falciparum malaria at the rate of 2 g/m^2 in 1982 after prolonged BHC spray (CHOUDHURY & GHOSH, 1982). SHARMA et al. (1983), SUBBARAO et al. (1984) reported that malathion resistance in *Anopheles stephensi* is monofactorial and codominant and this may have been one of the factors contributing to rapid build of resistance in the field populations. Reports of resistance to DDT have appeared in various states, such as Gujarat, Maharashtra, Rajasthan, Uttar Pradesh, Madhya Pradesh, Karnataka and Tamil Nadu RAGHAVAN et al., (1967; BHATNAGAR & WATTAL, 1979). Double resistance to DDT and BHC has been reported from Gujarat and Maharashtra by SHARMA & SAMNOTRA (1962). Resistance to DDT in *Anopheles stephensi* in adults was observed in Salem, Bhavani and Kumarapalvam (BHOMBORE et al., 1963). Due to spraying of malathion in 1982 in Sonepat district, the *Anopheles culicifacies* population was decimated and the malaria transmission completely interrupted while high densities of *Anopheles stephensi* were present. *Anopheles culicifacies* was susceptible to malathion in all the districts. *Anopheles stephensi* is a principal vector of malaria in Haryana state in urban areas. So the present study on susceptibility in different districts may be useful as baseline data for planning of malaria spray programme.

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BRIEF COMMUNICATION

THE SUBGENUS *HIRTODROSOPHILA* OF THE GENUS *DROSOPHILA* (DIPTERA : DROSOPHILIDAE) IN INDIA

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Taxonomic account of one new species, *Drosophila longiphallus* and new distribution records of two other species and one subspecies, *D. latifrontata*, *D. paralatifrontata*. and *D. latifrontata yakuensis* respectively are given. Key to the Indian species of *Hirtodrosophila* is also provided.

(*Key words*: New species, *Hirtodrosophila*)

The subgenus *Hirtodrosophila* Duda, 1923 of the genus *Drosophila* Fallen, 1823 comprises mostly fungivorous species. This subgenus, as now understood, contains over 100 species of *Drosophila* (Frota-Pessoa, 1945; Okada, 1967; Bock, 1982). Despite its cosmospolitan distribution, our knowledge of Indian species of *Hirtodrosophila* still remains very scanty and fragmentary. Altogether only four species namely *D. confusa* Staeger, *D. fascipennis* Okada, *D. neokurokawai* Singh & Gupta and *D. pentavittata* Gupta & Ray-Chaudhuri are known from India to-date (Gupta, 1981, 1985). This report deals with the description of three more species and one subspecies of this subgenus from India.

The species for the present study were collected from western ghats (S. India). Since species of *Hirtodrosophila* are fungivorous, all collections were therefore, made by net sweeping over a variety of mushrooms and other fungi or by aspirating them directly. The collected flies were then preserved in 70% alcohol on the spot itself. The taxonomic study was made following the procedure adopted by Gupta (1969).

Genus *Drosophila* Fallen

Drosophila Fallen, 1823, Diptera Sueciae Geomyz, 2:4. Type species: *Musca funebris* Fabricius, Sweden.

Subgenus *Hirtodrosophila* Duda

Hirtodrosophila Duda, 1923, Mus. Nat. Hungarici Ann. 22:41. Type species: *Drosophila latifrontata* Frota-Pessoa, Taiwan.

Third antennal segment considerably large and with unusually long bristles, arista with usually one ventral branch, anterior reclinate orbital fine, ventral receptacle in the form of loops folded flat against the ventral surface of vagina. Fungivorous species.

Drosophila longiphallus sp. nov.

Average length of the body: 3.22 mm (♂), 3.33 mm (♀).

Head, ♂♀: Arista with three dorsal and one ventral branches besides a large terminal fork. Antennae with second segment yellow; third segment elongate, brownish, with unusually long bristles. Frons including ocellar triangle pale to tan. Orbitals in

ratio of 2:1:2. Anterior reclinate orbital equally distinct from proclinate and posterior reclinate orbitals. Vibrissa single, strong; second oral not developed. Palpi pale yellow, distally somewhat darker, with only one prominent apical seta. Carina yellowish brown, low. Face brown. Cheek pale, brownish at margin, greatest width of the cheek 1/5 the greatest diameter of the eye. Clypeus dark brown. Eye dark red.

Thorax ♂♀: Mesonotum yellowish brown with three pairs of dark brown stripes, one pair of stripes along dorsocentral lines, another pair outside dorsocentral lines, incomplete, reaching anteriorly up to suture line and the outermost pair of stripes partially interrupted in middle. Thoracic pleura with three dark brown stripes. Acrostichal hairs in 8 irregular rows between dorsocentrals. Anterior scutellars convergent, posterior scutellars crossing each other. Distance between the anterior and posterior dorsocentrals about 1/3 the distance between the two anterior dorsocentrals. Humerals two, subequal. Sterno index 0.7.

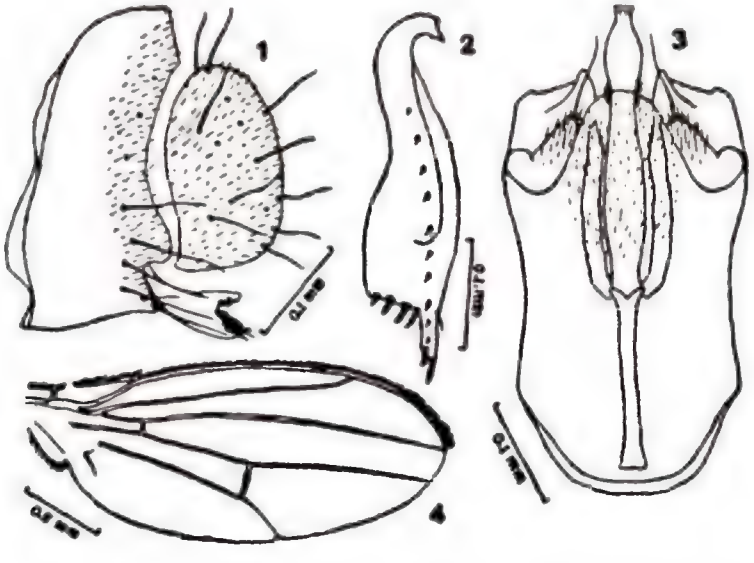
Legs pale yellow. Preapicals on all three tibiae; apicals on second tibia.

Wings, ♂♀ (Fig. 4): Clear. Approximate wing vein indices: C–index 2.0; 4V–index 1.6; 4C–index 1.0; 5X–index 1.5. C3 fringe 2/5. Halteres yellow.

Abdomen, ♂♀: Tergites yellowish, with brownish bands, protruding upward laterally.

Periphallic organs (Fig. 1): Epandrium broad, pubescent, with a small invagination at the insertion of surstylus and with 9 long bristles along posterior margin. Cercus oval, pubescent, with about 15 large bristles. Surstylus narrow, longer than broad, with 2 + 4 teeth arranged in a concavity.

Phallic organs (Fig. 2): Aedeagus unusually long, straight with a blunt tip, somewhat swollen submedially and with several fine hairs on dorsal surface; basal apodeme of aedeagus straight, smaller than aedeagus. Anterior gonapophyses elongate, apically with a few sensilla. Novasternum with a pair of long submedian spines. Ventral fragma longer than broad, distally rounded.



Figs. 1–4. *Drosophila longihallus* sp. nov.: 1. Periphallic organs; 2. Phillic organs; 3. Egg-guide; 4. Male wing.

Egg-guide (Fig. 3): Lobe orange yellow, long, abruptly narrowing apically and terminating in two stout unequal black teeth, with four obliquely placed discal teeth and about 10 minute marginal teeth. Basal isthmus short.

Holotype ♂, INDIA, KARNATAKA, Coorg district, Virajpet, June 1988 (Sundaran and Gupta). **Paratype:** 19 ♂♂ 33 ♀♀, same locality and collectors as holotype.

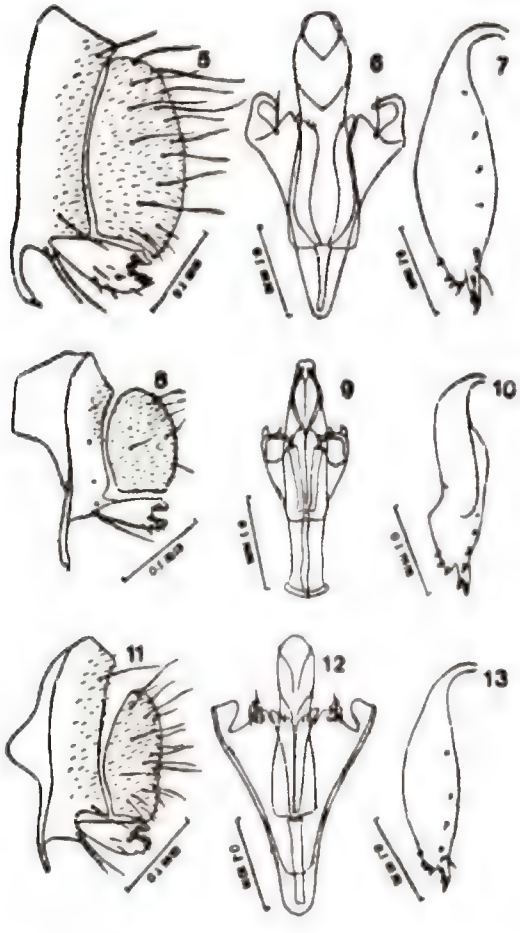


Fig. 5–7. *Drosophila latifrontata*: 5. Periphallic organs; 6. Phallic organs; 7. Egg-guide. Figs. 8–10. *Drosophila paralatifrontata*: 8. Periphallic organs; 9. Phallic organs; 10. Egg-guide. Figs. 11–13. *Drosophila latifrontata yakuensis*: 11. Periphallic organs; 12. Phallic organs; 13. Egg-guide.

Deposited in the Museum of Department of Zoology, Banaras Hindu University, Varanasi, India and Department of Biology, Tokyo Metropolitan University, Tokyo, Japan.

Relationships: The presence of considerably large third antennal segment with unusually long bristles, arista with one branch ventrally and the fine anterior reclinate orbital in this species justify its inclusion in the subgenus *Hirtodrosophila* of the genus *Drosophila*, wherein it closely resembles *D. mediohispida* Okada (1967) in general morphology, but clearly differs from it in having surstylus with 2+4 teeth (surstylus with 16 pointed black bristles irregularly arranged in *mediohispida*), unusually long aedeagus with a blunt tip (aedeagus narrowly pointed apically in *mediohispida*) and in many other characters of genitalia.

Distribution: INDIA.

Drosophila latifrontata Frota-Pessoa.

D. latifrontata Frota–Pessoa, 1945, Rev. Brasil. Bio. 5: 469–483.

Head, ♂ ♀ : Orbitals in ratio of 2:1:2. Face yellow. Clypeus pale brown. Vibrissa single.

Thorax, ♂ ♀ : Distance between anterior and posterior dorso-centrals 1/2 the distance between the two anterior dorsocentrals.

Abdomen, ♂ ♀ : Tergites whitish yellow.

Other details of morphological characters as well as male and female genital structures (Figs. 5–7) as described by Okada (1967).

Specimen examined: INDIA, KARNATAKA, Coorg district, Virajpet, 8 ♂♂ 2 ♀♀, June 1988.

Distribution: Formosa, Sumatra, Japan, India (New record).

Drosophila paralatifrontata Bachli.

D. paralatifrontata Bachli, 1973, Mitt. Zool Mus. Berlin, Bd. 49, Heft 2.

Head, ♂ ♀: Orbitals in ratio of 2:1:2. Greatest width of cheek 1/4 the greatest diameter of the eye.

Thorax, ♂ ♀: Distance between anterior and posterior dorsocentrals 1/2 the distance between the two anterior dorsocentrals.

Other details of morphological characters as well as male and female genitalia (Figs. 8–10) as described by Bachli (1973).

Specimen examined: INDIA, KARNATAKA, Coorg district. Virajpet 18 ♂♂ 23 ♀♀, June 1988.

Distribution: Formosa, Okinawa, India (New record).

Drosophila latifrontata yakuensis Okada.

D. latifrontata yakuensis Okada, 1967, Mushi, 41: 1–36.

This species closely resembles *D. latifrontata* Frota-Pessoa, but can be easily separated from the latter in having all the abdominal tergites uniformly dark, distally more gently dilated aedeagus and novasternum with a pair of spiny processes (Figs. 11–13).

Other details as described by Okada (1967).

Specimen examined: INDIA, KARNATAKA, Coorg district, Virajpet, 12 ♂♂ 25 ♀♀, June 1988.

Distribution: Japan, India (New record).

Remarks: The Indian form of this subspecies differs from the Japanese form described by Okada in having uniformly dark abdominal tergites (abdominal bands narrower and sharply demarcated in Japanese form.).

Key to Indian species of *Hirtodrosophila*

1 Wing with black patches ..... *fascipennis* Okada
– Wing without black patches 2
2 Mesonotum striped 3
– Mesonotum not striped 4
3 Abdomen with longitudinal stripes .....
– .....*pentavitttata* Gupta & Ray-Chaudhuri
– Abdomen without longitudinal stripes 5
4 Abdominal tergites with medially and laterally interrupted bands.....*confusa* Staeger
– Abdominal tergites with brownish uninterrupted bands ..... *neokurokawai* Gupta & Singh
5 Thoracic pleura with three brown longitudinal stripes ..... *longiphallus* sp. nov.
– Thoracic pleura without longitudinal stripes ... 6
6 Novasterum with a pair of spiny process .... *latifrontata yakuensis* Okada
7 Abdominal tergites whitish yellow .... *latifrontata* Frota-Pessoa
– Abdominal tergites black except two yellow terminal tergites ..... *paralatifrontata* Bachli

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BRIEF COMMUNICATION

OVICIDAL ACTIVITY OF INSECTICIDES ON EGGS OF BROWN PLANTHOPPER, *NILAPARVATA LUGENS* (STAL.) IN RESISTANT AND SUSCEPTIBLE RICE VARIETIES

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Foliar application of insecticides was tried on resistant and susceptible rice varieties which received the egg laying of brown planthopper, *Nilaparvata lugens* to evaluate the ovicidal activity of them. The plants treated with carbofuran and monocrotophos showed an eaverage egg hatch of 1.6 and 17.9 percent respectively. However, phosphamidon and decamethrin did not show significant difference in the percent egg hatch, since more than 70 percent egg hatch was observed on plants treated with them. The influence of varietal resistance on ovicidal activity of insecticides was not significant. But the effect was more on resistant and moderately resistant varieties.

(*Key words*: ovicidal activity, brown planthopper, resistant and susceptible varieties, nymphs, eggs)

From the last decade, the brown planthopper (BPH), *Nilaparvata lugens* (Stal.) (Homoptera; Delphacidae) has attained the status of major pest of rice throughout Asia (DYCK & THOMAS, 1979). It causes 'hopper burn' and also acts as a vector of grassy stunt and ragged stunt in the rice fields. Apart from controlling the adult BPH, some insecticides also prevent the egg hatch. RAO & RAO (1979) reported ovicidal activity of certain insecticides against BPH. The results of the laboratory experiments conducted to evaluate the ovicidal activity of some insecticides in resistant and susceptible rice varieties are furnished in this paper.

Glass house experiments were conducted at Tamil Nadu Agricultural University, Coimbatore to evaluate the ovicidal activity of certain insecticides *viz.*, carbofuran (Furadon 3 G), monocrotophos (Nuvacron 36 wsc) phosphamidon (Dimecron 85 wsc) and decamethrin (Decis 20 EC) at 0.5, 0.5, 0.4 and 0.001 kg ai/ha on 'PTB 33', 'IR 64' (resistant varieties), 'IR 36', 'CO 42' (moderately resistant varieties) and TN 1 (susceptible variety). When potted plants were 45 days old, they were treated with monocrotophos, phosphamidon and decamethrin through foliar sprays with the help of an atomizer (HANIFA & CHELLIAH, 1981) and carbofuran through root zone placement. Twenty - four hours prior to the treatment, each potted plant was introduced with five brachypterous females for oviposition.

The number of emerging nymphs daily from one week after spraying were observed and then removed. Observations were continued until no emergence of nymphs was noticed. The potted plants were then dissected and the number of unhatched eggs were counted. Finally the percentage of egg hatch was calculated as under (HEINRICHS *et al.*, 1984).

$$\text{Per cent egg hatch} = \frac{\text{Number of nymphs emerged}}{\text{Total eggs laid (no. of unhatched eggs + no. of nymphs emerged)}} \times 100$$

This experiment was conducted in a split – plot design with an untreated check as control. The varieties were considered as mainplots and the insecticides were the subplot treatments in each mainplot. Totally 25 treatments were obtained and each treatment was replicated 3 times. Data was transformed to arc sin values for statistical analysis and Duncan's Multiple Range Test (DMRT) was applied to compare the means (GOMEZ & GOMEZ, 1984).

The results revealed that the interaction effect of varietal resistance on the ovicidal activity of insecticides was not significant. However, significant differences were observed among the insecticides within a variety. Carbofuran and monocrotophos treated plants of all varieties showed less percentage of egg hatch (0.0 to 3.7% and 12.2. to 23.0% respectively). However, phosphamidon (60.0 to 77.8%), decamethrin (79.9 to 86.5%) and the untreated check (85.3 to 99.4%) treatments recorded high percentage of egg hatch in all the varieties and they were on par (Table 1).

When the individual effect of varieties and insecticides were considered, significant differences were observed. 'PTB 33' and 'IR 64' recorded significantly less egg hatch (47.6 and 49.4% respectively) compared to susceptible 'TNI', in which 58.1 percent of eggs hatched. Among insecticides, carbofuran

TABLE 1. Ovicidal activity of insecticides on the BPH eggs in resistant and susceptible rice varieties.

Insecticide	Percentage of egg hatch on					
	PTB 33	IR 64	IR 36	CO 42	TNI	Mean
carbofuran	0.0a A (4.1)	1.0a A (6.7)	1.6a A (8.4)	1.6a A (8.4)	3.7a A (11.8)	1.6a (7.9)
monocrotophos	12.2a A (20.5)	15.7a A (23.3)	19.4a A (26.1)	19.3a A (26.0)	23.0a A (28.7)	17.9b (24.9)
phosphamidon	60.8b A (51.3)	69.2b A (56.3)	76.0b A (60.7)	72.7b A (58.5)	77.8b A (61.9)	71.3e (57.7)
decamethrin	79.9b A (63.4)	74.8b A (69.9)	81.4b A (64.5)	77.7b A (61.9)	86.5b A (68.5)	80.1cd (63.6)
control	85.3b A (67.5)	86.1b A (68.1)	90.4b A (72.0)	90.6b A (72.2)	99.4b A (87.4)	90.4d (73.4)
	47.6A (41.4)	49.4A (41.4)	53.8B (46.3)	52.4B (45.4)	58.1C (51.7)	

For brevity data reduced to single decimal.
Figures in parentheses are arc sin transformed means.
In a column, means followed by a common letter (small letter) are not significantly different ($p=0.05$) and in a row, means followed by a common letter (capital letter) are not significantly different($p=0.05$) by DMRT.

followed by monocrotophos treatments recorded only 1.6 and 17.9 percent egg hatch respectively.

Ovicidal activity of insecticides on the eggs of *N. lugens* varied significantly within a variety but not among the varieties. This shows that varietal resistance has no influence on the ovicidal action of insecticides. In those plants treated with carbofuran, the eggs apparently completed embryonic development but did not hatch (HEINRICHS & VALENICA, 1981). RAO & RAO (1980) and GANESASN (1987) have reported that the eggs developed normally until the eye–spot phase and protruded out of the leaf sheath, but failed to hatch. Similar observations were also made in the present study. Earlier reports by several authors showed that carbofuran as foliar spray (VALENICA *et al.*, 1979; RAO & RAO, 1979; HEINRICHS & VALENICA, 1981) and as root zone placement (granules) (RAO & RAO, 1979; 1980; HEINRICHS & VALENICA, 1981) was effective against *N. lugens* eggs. A reduced egg hatching of only 13 percent for monocrotophos was also reported by KRISHNAIAH *et al.* (1982).

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Entomon 1990 Vol. 15 No. 3 & 4 pp. 267 to 269

BRIEF COMMUNICATIONS

A NEW SPECIES OF GENUS *DALUANA* RAMAKRISHNAN (CICADELLIDAE : TYPHLOCYBINAE : EMPOASCINI) INFESTING FIG AT RISHIKESH (UTTAR PRADESH) INDIA

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(*Received* 30 *July* 1989)

A new species *Daluana spinosa* sp. nov. infesting fig at Rishikesh, is described and illustrated. A key to the known species of genus *Daluana* is provided.

(*Key words:* *Daluana spinosa* sp. n., *Ficus carica* Linn., Rishikesh)

Daluana spinosa sp. n. (Figs. 1–12, 15)

General body colour fuscous brown. Head including eyes about as broad as pronotum. Eyes blackish, vertex with a round black spot on the anterior margin which runs on to the frons. Coronal sulcus visible at base. Vertex round anteriorly, twice as broad as long. Longitudinal depressed area present along the inner margin of each compound eye. Two grey spots in between the depressed areas and below the central black spot. Pronotum widened posteriorly, the posterior margin deeply concave. A transverse arcuate band and a connected posterior roundish patch on disc of pronotum black. Basal triangles dark fuscous. The margins of the scutellum and triangles yellowish brown.

Forewing smoky, wing margins and veins fuscous, bullar area fuscous; apex of cell R very acute, M broader with all apical veins arising from it, 3rd apical cell petiolate. Hind-wing thrice as long as its greatest width, M_{3+4} meeting Cu before stem of R + M.

Abdominal apodemes reduced, reaching up to the base of the 3rd abdominal segment.

Male genitalia:

Male subgenital plates fused up to the basal 3/4th, each provided with a mesal row of macrosetae and numerous microsetae in the lateral half of the disc. Paramere elongate, apically acute and with an outer spine-like process. The apical portion depicts various orientation when viewed from different angles (Figs. 6–9). Connective fused with aedeagus. Preatrium and dorsal apodeme very short, aedeagal shaft long, slender and bifurcated beyond gonopore, with inner margins of the prongs serrated. Pygofer (Figs. 11, 15) triangular having a sclerotic broader process on the upper margin; anal tube without well defined processes.

Female: Unknown.

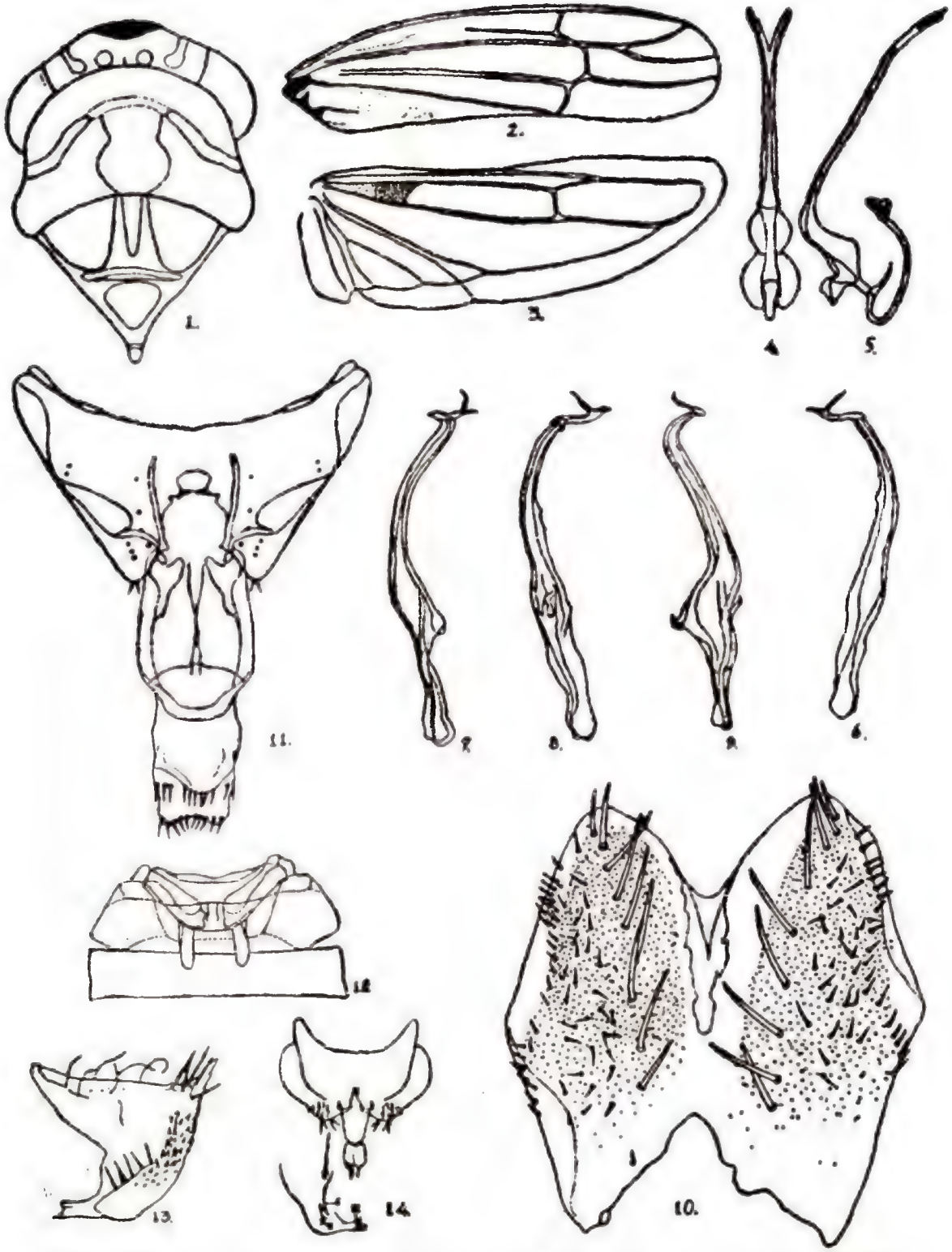
Measurements:

Body length of male – 3.96 mm.

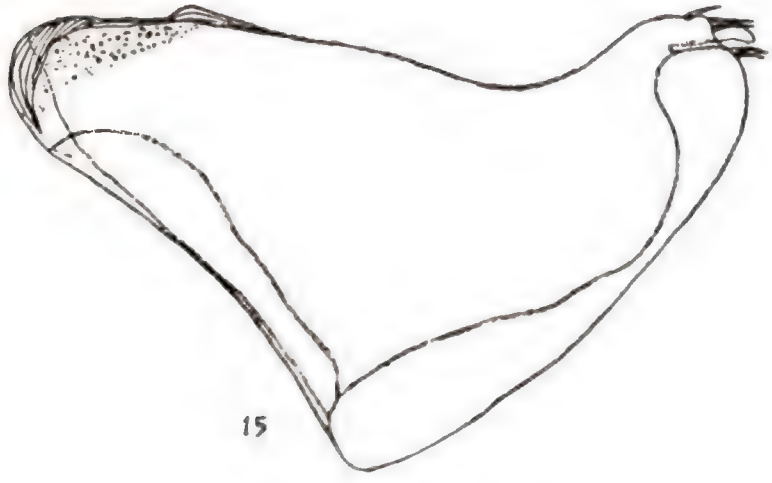
Head: Vertex length/breadth – 0.21/0.50 mm.

Interocular width (mean) – 0.50 mm.

Pronotum length/breadth – 0.48 mm/0.89 mm. Scutellum length/breadth – 0.50 mm/0.68 mm.



Daluana spinosa sp. n. (Figs. 1–12, 15). 1. Head & pronotum (dorsal view). 2. Forewing. 3. Hind-wing. 4. Aedeagus (dorsal view). 5. Aedeagus (lateral view). 6–9. Paramere (drawn from different angles), 10. Male subgenital plates. 11. Pygofer and anal tube (drosal view). 12. Abdominal apodemes. 13. Pygofer of *D. ramlyi* (redrawn from Dworakowska, 1984), and 14. Pygofer of *D. bhubaneshwarensis* (redrawn from Ramakrishnan, 1982).



15. Pygofer (lateral view) of *D. spinosa* sp. n.

Material examined:

Holotype: Male

Paratypes: 16 males

INDIA: UTTAR PRADESH, Rishikesh;

ex *Ficus carica* Linn.; 7.x.1985;

Coll. A.S. Sohi and J.S. Mann;

Holotype and 10 paratypes deposited in the National Pusa Collection, Division of Entomology, Indian Agricultural Research Institute; New Delhi; 2 paratypes each deposited in University of Agricultural Sciences (UAS), Bangalore; Forest Research Institute (FRI), Dehra Dun and Zoological Survey of India (ZSI), Calcutta.

Remarks: This species may be separated from *Daluana bhubaneshwarensis* and *D. ramlyi* in the shape of the apical part of the paramere, aedeagus and connective, and black spots in the middle of pronotum.

KEY TO THE SPECIES OF *DALUANA*

1. Tip of the paramere with a subapical spine-like process (Figs. 6–9) ..... *D. spinosa* sp. n.

– Tip of the paramere without process 2

2. Pygofer lobe apically acutely pointed and outwardly serrated (Fig. 13) ..... *D. ramlyi*

– Pygofer with 3 pairs of spinous processes (Fig. 14) ..... *D. bhubaneshwarensis*

ACKNOWLEDGEMENTS

The authors are thankful to the Professor and Head, Department of Entomology, Punjab Agricultural University, Ludhiana for providing the necessary laboratory facilities and to the Indian Council of Agricultural Research, New Delhi for financing the project in which the specimens were collected.

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BRIEF COMMUNICATION

FIRST RECORD OF THE GENUS *COLOCHELA* (HYMENOPTERA : TENTHREDINIDAE) FROM INDIA

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***Colochela* is recorded for the first time from India. The only species *C. rufidorsata* Malaise is redescribed from females in a schematic way with illustrations of clypeus, anal crossvein, tarsal claw and lancet.**

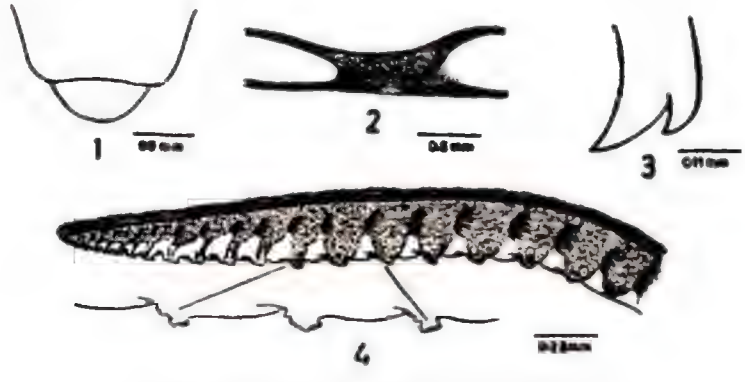
(*Keywords:* fiirst record, *Colochela*, India)

The monotypic genus *Colochela* was erected by Malaise (1937), taking *Colochela rufidorsata* Malaise as its type species. Malaise (1945) clarified that the type locality (Mouping) falls in the Szechuan province of China (Palaearctic region) and not Tibet as labelled by its collector A. David. This genus goes close to *Colochelyna* Konow and *Neocolochelyna* Malaise, but is characterised by having 3rd cubital cell much longer than 1st and 2nd combined and anal cell (Fig. 2) narrowed in its basal third having a very short perpendicular crossvein that is difficult to observe due to strong wing infuscation. This is the first record of this genus from India.

Colochela rufidorsata Malaise

Colochela rufidorsata Malaise, 1937. Rev. Franc. d'Ent., 4: 48. Female: Length, 17.0 mm. Body black, sanguineous are: pronotum except anterolateral and lateral aspects, mesonotum and mesoscutellum except posterior margin. Front wing distinctly infuscated, more strongly towards base; hind-wing clear; stigma and venation dark brown to black.

Antenna 1.7× head width, incrassate in middle, segments 3 and 4 in ratio 2:1; clypeus (Fig. 1) flat with slightly emarginate anterior margin; labrum broader than long with narrowly rounded anterior margin; malar space 0.5× diameter of median ocellus; LID : IDMO = 4:5; length and width of eyes in ratio 5:4; OOL : POL : OCL = 4:3:5; frontal area almost at level of eyes; supra-antennal tubercle strongly raised and confluent with somewhat low frontal ridge; lateral



Colochela rufidorsata Malaise, Female. Figs. 1–4.
1. Clypeus; 2. Anal cross vein; 3. Tarsalclaw; 4. Lancet.

fovea deep; median fovea in the form of broad and deep pit, having a tubercle each between antennae and in front of median ocellus; circum– and interocellar furrows deep and sharp; postocellar furrow broad and shallow; lateral furrows sunken and excurved; postocellar area flat, broader than long in ratio 3:2 at maximum width; head somewhat dilated behind eyes; mesoscutellum almost flat with faint indication of longitudinal carina; appendage not carinate; mesepisternum obtusely elevated; mesosternum without thorns but faintly angled; subapical tooth of claw (Fig. 3) longer than apical; metabasitarsus subequal to following three tarsal joints combined; metafemur and tibia in ratio 4:5. Lancet as shown in Fig. 4.

Head and thorax minutely and densely punctured with dense and long pubescence, scutellar appendage polished; abdomen faintly wrinkled and minutely punctured.

Material examined: 2♀♀, Meghalaya, Smit, 1600m, 20.v.1986.

Distribution: India–Meghalaya; China.

ABBREVIATIONS

IDMO – Interocular distance at level of median ocellus; LID – Lower interocular distance; OCL – Ocello-occipital line; OOL – Ocello-ocular line; POL – Post-o cellar line.

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BRIEF COMMUNICATION

THE EFFECT OF CARBOFURAN APPLIED ON THE CONTROL OF PESTS OF ROSES

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(*Received* 15 *December* 1989)

A pot culture experiment to study the effect of different doses of carbofuran applied for the control of the insect and mite pests of rose revealed that the application of carbofuran was effective at doses higher than 0.15 g ai/plant especially for controlling the population of *R. syriacus*, *A. aurantii* and *T. neocaledonicus* and the damage caused to flower buds and leaves by *S. dorsalis*.

(*Key words*: carbofuran, pests of rose)

Judicious pesticide management programme has to be developed for the successful growing of rose, because the budded roses are very often protected from the ravages of the pests and diseases using plant protection chemicals in regular schedules. This intense use of plant protection chemicals has already created resistance problems in the management of pests in the rose gardens. Hence, a pot culture trial was conducted to study the effect of varying doses of carbofuran on the control of insect and mite pests of rose in the Instructional Farm, Vellayani during 1986.

Carbofuran (Furadan 3G supplied by M/s. Rallis India Ltd.) was applied at six doses (Table 1) to the soil in the pot around the plant after raking the soil. Controlled irrigation was given @1.5 litres of water/pot (size 30 × 30 cm). Each treatment was replicated four times in CRD. Observations on the population of *Retithrips syriacus*, *Aonidiella aurantii* and *Tetranychus neocaledonicus* and the damage caused by *Scirtothrips dorsalis* were recorded. The population of *R. syriacus* was assessed by counting the total number of thrips present on ten older leaves and the scale insects, *A. aurantii*, by counting from one cm length each from the basal, middle and the top regions of the infested part of the stem in each plant. In the case of the thrips *S. dorsalis*, the percentages of damaged leaves and the flower buds were estimated. The mites were counted from five older leaves, selected at random, from each plant.

The results (Table 1) showed that at seventh day after application, the population of *R. syriacus* on the plants treated with carbofuran at the higher two levels of 0.15 and 0.18 g ai/plant (17.2 and 13.1, respetctively) were significantly lower than that in the untreated control, whereas the population in all the other doses was on par with that of control, which recorded a mean population of 44.32. A more or less same trend was observed on the 14th day after application also.

Data on the effect of different doses of carbofuran on the population of *A. aurantii* at seven days after treatment showed that carbofuran could control the pest effectively only at the highest dose (0.18 g ai/plant), whereas the population in all the other doses (9.33 to 11.33) came on par with that

TABLE 1. Effect of carbofuran applied at different doses on the control on insect and mite pests of rose.

Dose g ai/pot	Mean population observed at different intervals after spraying (days)						Mean percent damage observed at different intervals after spraying (days)			
	R. syriacus		*A. auranti*		*T. neocalidonicus*		*S. dorsalis*		*S. dorsalis*	
							Leaf		Flower bud	
	7	14	7	14	7	14	7	14	7	14
0.03	37.00 (5.81)	46.10 (6.68)	9.33 (3.11)	14.67 (3.81)	23.67 (4.72)	39.33 (6.19)	72.33 (8.56)	80.00 (8.82)	69.33 (8.30)	81.67 (8.92)
0.06	42.80 (6.37)	39.20 (6.14)	11.33 (3.19)	11.67 (3.26)	26.67 (5.21)	32.67 (5.76)	68.67 (8.21)	57.33 (7.46)	72.00 (8.38)	89.33 (9.39)
0.09	31.30 (5.46)	29.60 (5.28)	9.67 (3.08)	12.33 (3.40)	18.67 (4.20)	36.10 (5.91)	70.33 (8.31)	48.00 (6.86)	61.67 (7.78)	67.00 (8.08)
0.12	36.10 (6.01)	23.10 (4.96)	10.33 (3.24)	13.67 (3.59)	21.33 (4.60)	27.33 (5.14)	49.33 (6.95)	61.67 (7.84)	52.67 (7.14)	75.33 (8.56)
0.15	17.20 (4.10)	10.25 (3.32)	9.33 (3.17)	10.67 (3.06)	13.33 (3.59)	20.67 (4.46)	26.32 (5.07)	42.67 (6.44)	81.33 (9.06)	87.00 (9.28)
0.18	13.10 (3.57)	2.30 (1.44)	6.33 (2.40)	7.33 (2.66)	9.67 (3.06)	15.33 (3.91)	28.67 (5.33)	37.33 (6.10)	68.33 (8.19)	43.33 (6.51)
Control	44.32 (6.67)	39.21 (6.18)	12.67 (3.48)	13.33 (3.61)	22.33 (4.81)	28.67 (5.28)	80.00 (8.88)	86.67 (9.28)	92.00 (9.46)	100.00 (9.68)
CD (at 5% level)	1.85	1.92	0.61	NS	1.72	1.81	1.82	1.73	NS	1.32

Figures in parentheses are transformed values (x + 1).

of control. By fourteenth day after treatment even the highest dose failed to reduce the population significantly over control.

As in the case of *A. aurantii*, the population of *T. neocaledonicus* was also reduced significantly over control, when treated at the highest dose of 0.18 g ai/plant, the mean population being 9.67. The same trend was noticed on fourteenth day after treatment also.

In the case of the leaf damage by *S. dorsalis*, the treatments with carbofuran at the higher three doses of 0.12, 0.15 and 0.18 g ai/plant could reduce the damage on tender leaves significantly over control at the seventh day after application, but the lower levels of 0.03, 0.06 and 0.09 g ai/plant failed to exert any significant effect on the damage. At fourteenth day after treatment the leaf damage in the plants treated with carbofuran at the higher four doses was significantly lower than that in the lower two doses and untreated control.

In the case of flower damage by *S. dorsalis*, no significant reduction in the damage could be seen even in the highest dose of 0.18 g ai/plant at seven days after treatment. But, from the data at the fourteenth day after treatment it is seen that the percentage of damage was significantly lower in plants

treated at the dose of 0.09 and 0.18 g ai/plant, the damage being 67.0 and 43.33 percent, respectively, while 100 percent damage was observed in control.

Considering the effect of varying doses of carbofuran in controlling different pests of rose it may be concluded that application of carbofuran was effective only at doses higher than 0.15 g ai/plant. Similar studies conducted by SREENIVASAN *et al.* (1974) revealed that carbofuran at 1.5 kg ai/ha gave best control of the scale insect, whereas carbofuran at 0.3 g ai/plant was reported to be the most effective insecticide for the control of *A. aurantii* on rose NANDAKUMAR *et al.* (1988).

Thus, in homestead gardens with 25-50 potted plants, a systemic broad spectrum insecticide like carbofuran will be the most ideal insecticide for the control of the different pests of rose because of the convenience and safety of application.

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BRIEF COMMUNICATION

RHACHISPHORA ELONGATUS SP. NOV. (ALYRODIDAE: HOMOPTERA) - A NEW SPECIES OF WHITEFLY FROM INDIA

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A new species of whitefly *Rhachisphora elongatus* sp. nov. collected from *Mimusops elengi* L. at Kunnathoor, Kanyakumari district, Tamil Nadu is described and illustrated.

(*Key words*: *Rhachisphora elongatus*, *Mimusops elengi*, Aleyrodidae)

Mound & Halsey (1978) have reported *Rhachisphora trilobitoides* (Q. & B). as the only species known from India under the genus *Rhachisphora*. In the present paper a new species of *Rhachisphora* collected from *Mimusops elengi* L. is described and illustrated.

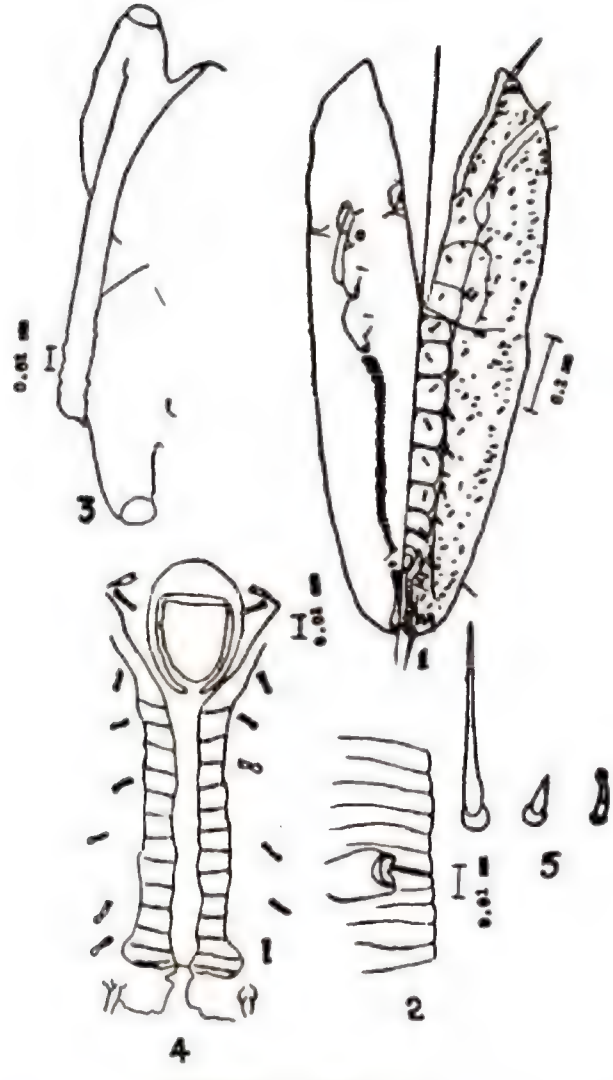
Rhachisphora elongatus sp. nov. (Figs. 1–5)

Pupal case: Much elongated, white with little wax all over the body; found along veins on the under surface of leaves, broadest at the second abdominal segment area; 1.42–1.47 mm long and 0.52–0.55 mm wide. *Margin :* Regularly crenate, 16–17 crenations in 0.1 mm; paired anterior marginal setae 20–22.5 μm long, and posterior marginal setate 27.5 μm long. Thoracic and caudal tracheal pores distinct.

Dorsal surface : Submargin not separated from the dorsal disc. Longitudinal moulting suture reaching margin and transverse moulting suture reaching the submarginal area. A pair of ridges extending from the cephalic region (diverging anteriorly and nearly reaching the margin) to the abdomen laterad of caudal furrow evident. Rhachis well developed in the median area and not reaching the margin. All the eight abdominal segments and meso- and metathorax contain rhac. Each abdomninal segment contains a small median rectangular marking. Cephalothorax 0.62 - 0.65 mm and abdomen 0.80 - 0.82 mm long. Eye spots absent.

Five pairs of lanceolate dorsal setae-cephalic setae 3.75–5 μm long, a pair below the cephalic setae 3.75-5 μm long, first and eighth abdominal setae 5–7.5 μm long each, and caudal setae 50–55 long. Four pairs of submarginal lanceolate setae–a pair of long setae at the anterior region 52.5-57.5 μm long, a small seta below the long setae 7.5μm long a pair in the cephalic ridge 27.5 μm long and a pair above the caudal setae 15 μm long. A row of eight pairs of small submarginal spines — three on the cephalothorax and five on the abdomen 2.5-5 μm long. Dorsum contains about 80 pairs of capitate setae – 35 pairs on the cephalothorax and 45 pairs on the abdomen, 12.5–15 μm long. Dorsum also possesses about 56 pairs of pores and porettes - 26 on the cephalothorax and 30 on the abdomen sparsely distributed. A pair of brown patch present on the metathorax.

Vasiform orifice : Subcordate shaped with thick lateral walls, notched at the hind end. longer than wide, 62.5 – 67.5 μm long and 50–52.5 μm wide; operculum similarly shaped, 37.5 μm long and 30 μm wide, filling the orifice, concealing the lingula. Caudal furrow long and narrow 127.5–132.5 μm long and 12.5 μm wide.



Rhachisphora elongatus sp. nov.
Fig. 1 – Pupal case; Fig. 2 – Thoracic tracheal pore; Fig. 3 – Antenna;
Fig. 4 – Vasiform orifice and caudal furrow; Fig. 5 – Different types of dorsal setae.

Ventral surface : Paired ventral abdominal setae 45 μm long and 42.5 μm apart. Thoracic and caudal tracheal folds present. Caudal tracheal fold 50 μm wide in the anterior region and posterior region bulged 72.5 μm wide. A seta present at the base of each meso- and metathoracic leg, 5 μm long. Antenna very long reaching beyond the middle of the mesothroacic leg, 175 μm long. Stipples present from the distal end of metathoracic leg to the vasiform orifice through the submedian ridges and from the base of vasiform orifice to the middle of the caudal fold.

Materials exmined :

Holotype : One pupal case mounted on slide, on *Mimusops elengi L.* (Sapotaceae), Kunnathoor (Tamil Nadu), 24.i.1989. Coll. K. Regu.

Paratypes : 15 pupal cases on slides bearing the same details as of holotype of which one has been deposited in the collections of the Division of Entomology, Indian Agril. Res. Institute, New Delhi, pupal cases on leaves in the collections of K. Regu.

This species is closely related to *Rhachisphora reticulata* (Takahashi, 1933) in the shape of pupal case, rhachis and presence of capitate and lanceolate setae but differs from that in the absence of reticulations on the dorsum and presence of thoracic tracheal folds and stipples from the base of metathoracic leg to the vasifrom orifice.

Thanks are due to Mr. S. JAMES FREDRICK, Chairman, Frederick Institute of Plant Protection & Toxicology, Padappai, for facilities provided.

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Entomon 1990 Vol. 15 No. 3 & 4 pp. 281 to 282

BRIEF COMMUNICATION

A NEW *ERYNGIOPUS* SUMMERS (ACARI: STIGMAEIDAE) FROM INDIA

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(*Received* 1 *December* 1989)

A new species of *Eryngiopus* (Acari: Prostigmata) from India is described and illustrated.

(*Key words*: *Eryngiopus coimbatorensis*, new mite, Coimbatore, Tamil Nadu, India)

So far the family Stigmaeidae is known from India by the genera *Agistemus* Summers and *Indostigmaeus* Gupta & Ghosh (Gupta, 1985) occurring on p'ants, while *Cheylostigmaeus* Willmann and *Stigmaeus* Koch are known from birds' nests (Gupta & Paul, 1985). However, the genus *Eryngiopus* Summers is hitherto unknown from India but its occurrence has been recorded from Thailand (Ehara & Wongsiri, 1984) and New Zealand (Wood, 1967; 1971). The junior author of the paper collected this mite from sugarcane in association with sugarcane scale insect, *Saccharicoccus sacchari* (Cockerell) and the same is described and illustrated here as new species. The measurements given here are in μm. The types are in the National Collection of the Zoological Survey of India, Calcutta.

Eryngiopus coimbatorensis sp. nov. (Figs. 1–4)

Female : Propodosomal plates confined to a small area as figured separated by longitudinal striations but contiguous at the anterior tip bearing setae ae, be and a pair of eyes. Setae ae and be measure 9 and 13, respectively. The other two pairs of propodosomal setae, *viz.* ce and de measure 18 and 22, respectively. All the propodosomal setae short, narrow and simple. Propodosomal integument posterior to plate mostly with longitudinal striation. Setae he short, 17 long. Hysterosoma mostly longitudinally striated with setae a, b, c, la, lm and li, all lie on integument and measure 20, 14, 14, 18, 14, and 27, respectively. Suranal plate single, ill-defined bearing setae e and le and measure 26 and 27, respectively. All setae short, slender and simple. Setae li, le and e being slightly stouter than other dorsal setae. Seta lm is nearer to li than to la. The measurements/distances/ratios of different setae are: a–a = 85, b–b = 42, c–c = 40, e/le = 1.1, ae/ae – ae = 0.18, a/a-a = 0.23, c/c-c = 0.35. Paragenital setae 3 pairs; anogenital setae 4 pairs. Setae ag_3, ag_4 longer than ag_1 and ag_2. Palp terminal sensillum road-like without fork. Chaetotaxy of legs I-IV as follows:

	femur	genu	tibia	tarsus
I	3	1	5	8
II	3	1	5	8
III	2	1	4	4
IV	2	1	4	6

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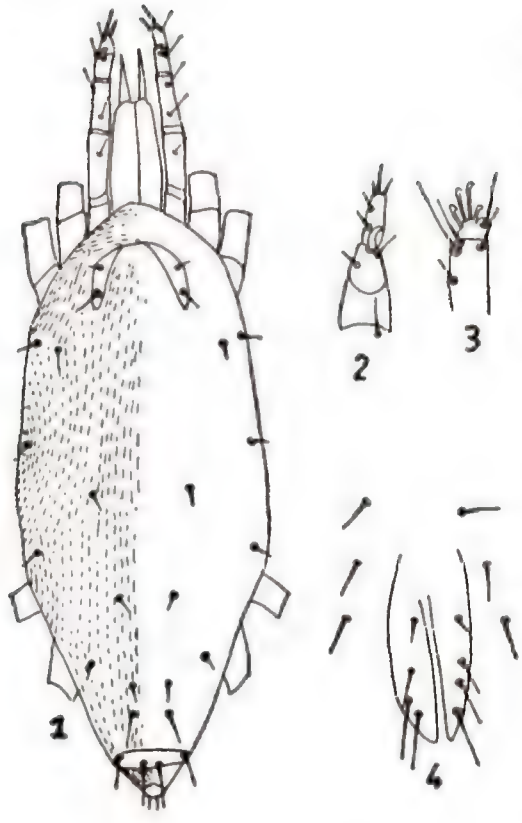

Figs. 1–4. *Eryngiopus coimbatorensis* sp. nov: (Female) :
1. Dorsal surface, 2. Palp tibia and tarsus, 3. Tarsus I, 4. Ventral opisthosoms.

Male : Unknown.

Holotype : ♀ INDIA : TAMIL NADU, Coimbatore ex sugarcane, associated with scale insect, *Saccharicoccus sacchari* (Cockerell), 6. iv. 1989, coll. H. David.

Paratypes : 3 ♀♀, data same as for holotype.

Remarks : This new species is related to a number of species, *viz. E. arboreus* Wood (1967), *E. similis* Wood (1967), *E. bifidus* Wood (1967), *E. nelsonnensis* Wood (1971) and *E. yasumatsui* Ehara & Wongsiri (1984). Because of having single suranal plate and simple palp terminal sensillum, it is very closely related to *E. arboreus* but differs in having a/a-a $>$ 1 in *arboreus* and a/a-a $<$ 1 in this new species. Besides, li, le and e are all subequal here but li shorter than le and e in *arboreus*. From *E. similis*, it differs in not having forked terminal sensillum and from *E. nelsonensis* in having only 3 setae against 5 in the latter. Lastly, it can also be distinguished from *E. bifidus* in having 2 genual setae (none in *bifidus*) and *E. yasumatsui* in having differences in leg chaetotaxy as well as in relative ratios of idiosomal setae.

ACKNOWLEDGEMENT

The first author is thankful to Prof. M. S. Jairajpuri, Director, Zoological Survey of India, for the facilities.

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BRIEF COMMUNICATION

FEEDING BEHAVIOUR OF *CHRYSOPERLA CARNEA* (STEPHENS) ON THE PARASITIZED PUPAE OF *BEMISIA TABACI* (GENNADIUS)

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(*Received* 20 *November* 1989)

The green lacewing, *Chrysoperla carnea* (Stephens) was found praying on the cotton whitefly, *Bemisia tabaci* (Gennadius) in cotton field under Parbhani conditions. *Bemisia tabaci* pupae were also found parasitized by 6 aphelinid parasitoids which caused good parasitism to the extent of 25–63 percent during September-November. The experiment was, therefore, conducted to ascertain whether the predator attacks the parasitized in addition to the healthy pupae of this pest.

The whitefly pupae parasitized by an aphelinid, *Encarsia transvena* (Timberlake) were used. Third instar larva of *C. carnea* was exposed to fifty parasitized host pupae in a petri dish. Similarly, in the other treatments, fifty parasitized pupae in addition to 30, 50 and 100 healthy pupae were exposed to each larva. At the same time fifty parasitized pupae were kept unexposed as a control. The larvae were removed from all the sets after 24 hours of exposure and pupae of whitefly were kept separately in glass tubes until the emergence of parasitoids. The percentage of adult emergence in each set was worked out. The results obtained are presented in Table 1.

It was evident from the data presented in Table 1 that in captivity condition the larva of this predator was found to feed on the parasitized host pupae when exposed to only these pupae and allowed only 29.00 percent emergence of adult parasitoids from the exposed ones as compared to 85.50 percent emergence in control, wherein parasitized host pupae were not exposed to predation. Further, the percentage emergence of adult parasitoids was increased when the number of healthy pupae were increased along with the parasitized ones for providing the chance of food choice.

There was no significant difference in percentage emergence between exposure no 4 *i. e.*, 50 parasitized pupae in addition to 100 healthy ones (83.50 percent) and control (85.50 percent). Thus, it clearly indicated that the larva predated on the parasitized pupae only in the absence of the sufficient healthy pupae.

FORER & GERLING (1984) reported that the death of immature parasitoids of whitefly was sometimes caused through predation by *C. carnea*. The larvae of predator, *Chrysopa sclelestes* Banks readily attacked eggs of lepidopterous pests parasitized by *Trichogramma* spp. (KRISHNAMOORTHY & MANI, 1985). The results of the present investigation are in conformity with the observation of FORER & GERLING (1984).

TABLE 1: Emergence of *Encarsia transvena* adults from the parasitized *B. tabaci* pupae exposed to *C. carnea* larva.

Sl. no.	No. of host pupae allowed per larva	Adult emergence (%)*
1	50 parasitized pupae	29.00 (32.55)
2	50 parasitized pupae + 30 healthy pupae	46.00 (42.70)
3	50 parasitized pupae + 50 healthy pupae	62.50 (52.35)
4	50 parasitized pupae + 100 healthy pupae	83.50 (66.22)
5	50 parasitized pupae alone (control)	85.50 (68.00)
	S E ±	1.83
	C D ($P = 0.05$)	5 43

Figures in parentheses indicate the transformed values.

* Average of 4 replications.

It was also observed that in captivity this predator fed upon the parasitized nymphs of cotton aphid, *Aphis gossypii* Glover when insufficient number of aphids were provided during its rearing in laboratory. TREMBLAY (1980) had reported that the predator, *Chrysopa formosa* Br. even attacked the aphids, *Aphis fabae* Scop. and *A. craccivora* Koch. parasitized by the braconid, *Lysiphlebus fabarum* (Marshel).

The results of the present study showed that the release of chrysopid in cotton field should be avoided in an area where the parasitism of cotton whitefly is more, to get the benefit of natural biocontrol.

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REPPORTS AND NEW RECORDS

NOTE ON THE UTILITY OF *NEOCHETINA* SPP. (COLEOPERA : CURCULIONIDAE) IN THE CONTROL OF WATER HYACINTH, A HOST FOR MANSONIOIDES BREEDING

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(*Received* 22 *February* 1990)

Small scale field trial showed that the use of *Neochetina* spp., though useful in the elimination of water hyacinth resulted in the infestation of other aquatic weeds which are the most preferred host plants of mansonioides mosquitoes.

(*Key words*: *Eichhornia crassipes, Neochetina eichhorniae, Neochetina bruchi,* mansonioides control)

Eichhornia crassipes, the water hyacinth ranks first among the noxious floating macrophytic hydrophytes. *Neochetina eichhorniae* and *N. bruchi* are reported to be effective bio-control agents against water hyacinth (JAYANTH, 1987). A small scale field trial was carried out in Shertallai, Kerala to assess the utility of these weevils in the control of water hyacinth to the roots of which the larvae of mansonioides mosquitoes, the vectors of malayan filariasis attach for respiration. The results are presented here.

A closed channel having a surface area of 160 sq.m. and a depth of 1.5 m, infested with *E. carssipes* was selected for the study. Adults of about 1400 weevils belonging to *N. eichhorniae* and *N. bruchi* in the ratio of 1:2 were released in the channel, and observed at monthly intervals. A similar channel without weevils was also monitored for comparison.

Feeding scars in the laminae of weeds were noticed from the first month with maximum towards the fourth month. Visible damage of the petiole and crowns, due to tunnelling and feeding of larvae of these weevils was seen from the fourth month onwards. It was subsequently increased with a complete destruction of weeds at the end of seventh month. Further observations showed that *Pistia stratiotes* and *Salvinia molesta* started sprouting in the weed free area and at the end of tenth month, the whole area was occupied by these weeds. In the control channel there was no change in the infestation status, as the whole surface area was fully choked with water hyacinth. A long-term observation on the effect of these weevils has shown that over 90% of suppression of this aquatic weed over a period of 3 years (JAYANTH, 1987).

It is evident from this study that once the water hyacinth is eliminated from a habitat, it paves way for the reinfestation with other weeds especially the *P. stratiotes,* the most preferred plant of *M. annulifera* which is the principal vector of malayan filariasis in this area. Hence elimination of water hyacinth alone, employing these weevils which are host specific is not advantageous in the control of vectors of malayan filariasis.

ACKNOWLEDGEMENT

The authors are highly grateful to the Director, Vector Control Research Centre

for the constant encouragement of this study and Indian Institute of Horticultural Reserach, Bangalore for the supply of *Neochetina* spp. for the trials.

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TIRATHABA MUNDELLA WALKER (PYRALIDAE: LEPIDOPTERA) A NEW FRUIT BORER OF MANGO IN SOUTH ANDMAN (INDIA)

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(*Received* 30 *July* 1989)

***Tirathaba mundella* Walker, a pyralid moth is reported for the first time from India as a fruit borer of mango.**

(*Key words*: *Tirathaba mundella*, Andamans, mango)

During a survey in April 1988, to Viper island of Andaman and Nicobar Islands, severe fruit borer infestation in mango (*Mangifera andamanica*) was found. The pest was subsequently identified as *Tirathaba mundella* Walker. Perusal of literature revealed that this has not been recorded on mango earlier. The extent of infestation was 17 percent. The reddish brown larvae were observed boring and feeding on the pulp and stone. The bored fruits either dropped prematurely or were found webbed together in each bunch. Usually one and occasionally two larvae per fruit were observed. A single larva was also seen attacking more than one fruit in the early stages after fruit set and the infestation was continuous. Pupation took place in soil.

The adult is a medium sized moth with an approximate wing span of 20 mm. Fore and hind-wings are dark straw coloured without any specific markings. There was no much difference between the sexes. Many species of *Tirathaba* have been reported

Fig. 1. *Tirathaba mundella* Walker

attacking crops. *T. rufiveno* attacks the flowers and nuts of oilpalm in Malaysia (NG, 1982), *T. complexa* and *T. rufivena* on coconut spikes in Philipines (GODFRAY, 1985) and *T. mundella* on the flowers and nuts of arecanut in India (ABRAHAM *et al.*, 1962), and *Tirathaba* sp. on the nuts of coconut in India (NAIR, 1975). The attack of *T. mundella* on fruit crops is not so far reported from India. This is the first report of *T. mundella* attacking mango fruits in India from South Andaman.

ACKNOWLEDGEMENT

The authors are grateful to the Director, Central Agricultural Research institute for providing facilities to conduct the survey and to Dr. M. SHAFFER, British Museum (Natural History), London for the identification of the insect.

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CAMPOLETIS CHLORIDEAE (UCHIDA) (HYMENOPTERA: ICHNEUMONIDAE) A NEW HOST OF *BRACHYMERIA SECUNDARIA* (RUSCHKA) (HYMENOPTERA: CHALCIDIDAE)

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(*Received* 22 *October* 1989)

Brachymeria secundaria **(Ruschka) a known Hyperparasite of Braconidae is first time recorded on a Ichneumonid –** *Compoletis chlorideae* **(Uchida), a potential parasite of gram pod borer,** *Heliothis armigera* **Hub.**

(*Key words*: *Brachymeria secundaria*, hyperparasite, *Compoletis chlorideae*)

During field study of parasitic potential of *Compoletis chlorideae* Uchida on gram pod-borer *Heliothis* armigera Hub. during 1988, considerable number of *C. chlorideae* cocoon were found hyperparasitised by *Brachymeria secundaria* Ruschka. This hyperparasite was active in the field of gram from 1st fortnight of November and gradually hyperparasite population increases and ultimately peak (9.6%) was observed in the 2nd fortnight of February, subsequently population level decreases.

Search of available literature suggested that this chalcidid hyperparasite was earlier reported as a primary parasite of Lymantriidae, Pieridae and Olethreutidae (THOPSON, 1955), and hyperparasite of *Apanteles lisparidis, A. ordinaris, Meteorus* sp., *M. rubens. M. versicolor, Rhogas* sp. and *R. drymoniae* (Braconidae) (JOSEPH *et al.*, 1973; NAREDRAN, 1989).

This is the first time when *B. secundaria* is recorded as a hyperparasite of Ichneumonidae.

ACKNOWLEDGEMENT

The authors express their gratefulness to Dr. T. C. NARENDRAN, University of Calicut for the help rendered in identification of hyperparasite.

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AUTHOR INDEX

ANNOUNCEMENTS

PROF. M. L. ROONWAL

With profound grief and sorrow we inform
the sad demise of Prof. M. L. Roonwal
(born Sept. 18, 1908)
formerly Chief Forest Entomologist,
Director, Zoological Survey of India and
Vice Chancellor, Jodhpur University,
on July 22, 1990.

R. C. SHARMA

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INTERNATIONAL SYMPOSIUM ON TROPICAL CROP RESEARCH AND BIOTECHNOLOGY

(September 1991, Trivandrum, Kerala, India)

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BRIEF COMMUNICATIONS

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